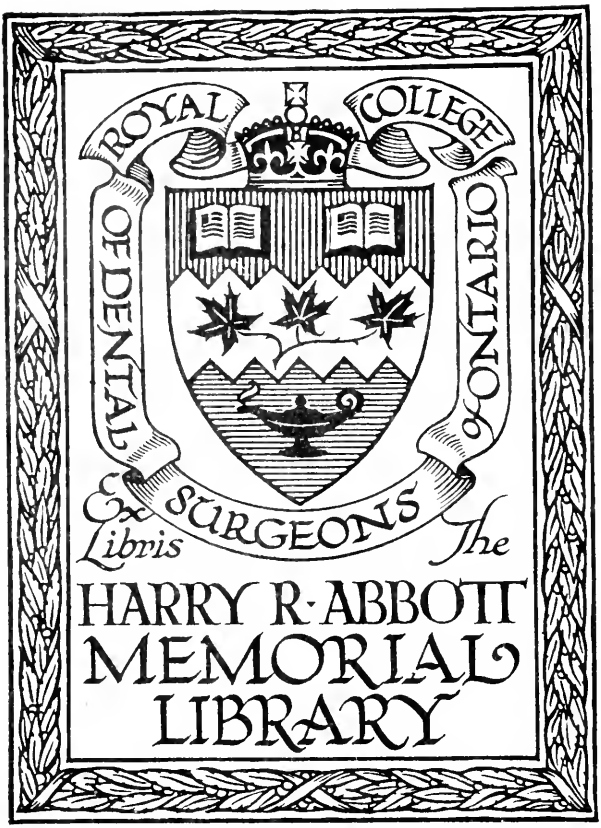

ROYAL COLLEGE
OF DENTAL SURGEONS
ONTARIO
Ex Libris The
HARRY R. ABBOTT
MEMORIAL
LIBRARY

33
40

Digitized by the Internet Archive
in 2011 with funding from
University of Toronto

http://www.archive.org/details/manualofcomparat00thom

A MANUAL

OF

COMPARATIVE

DENTAL ANATOMY

FOR

DENTAL STUDENTS.

Prepared by request of the National Association of Dental Faculties and adopted as a text-book for colleges August 27, 1898.

BY

ALTON HOWARD THOMPSON, D.D.S.,

TOPEKA, KANSAS.

Professor of Dental Anatomy, Human and Comparative, in the Kansas City Dental College, Kansas City, Mo.

WU
G101
T46

PHILADELPHIA:
THE S. S. WHITE DENTAL MFG. CO.
1899.

Copyright, 1898, by ALTON H. THOMPSON.

PREFACE.

My apology for the presentation of this little book as a candidate for the favor of my colleagues, the teachers in the Dental Colleges of the United States, is, that there is a real and pressing need for a concise compendium of Comparative Dental Anatomy for the use of dental students. The general works on this subject are not adapted to the special needs of the student of dentistry, and it is the mission of this manual to select and arrange for him just the material he will require for the illumination of his studies of the human teeth by comparison with the teeth of lower animals and the philosophy of tooth forms, without going into the elaborate and cumbrous details of the subject. These details can be found in the larger works if he should desire to pursue the subject further.

The sifting out of the special matter here presented from the mass of material bearing on the subject in the literature of zoology has been the work of years, and represents the gleanings from many fields. Its matter and methods have been slowly evolved through the needs of the work of teaching this branch in the class-room, and it is with the hope that it will be useful to the teachers

of this branch that this little manual is offered to them.

Many branches of science are laid under contribution to supply material for our special needs as dentists, and it is the province of dental text-books and teachers to select from the general store of accumulated facts just those which will be of service to the dental specialist; so Comparative Dental Anatomy is drawn upon for the sidelights it throws upon human odontography, as to both tooth forms and functions, as well as for the scientific study of the evolution and philosophy of tooth forms. The time was when it was necessary to apologize for the intrusion of Comparative Dental Anatomy into the curriculum of dental education; but it is a matter of congratulation that the value of this branch as an element in our professional education is now generally recognized. The study of the forms and functions of the teeth of other animals than man, as a means of conveying a better understanding of the forms and functional purposes of the human teeth, is now fully appreciated. It is also recognized that this study furnishes the only scientific elucidation of the origin and principles of these forms and functions, which had heretofore been taught by the study of the human teeth alone.

In regard to the general scheme of the book, it must be stated that some liberties have been taken with the usual zoological classifications in order to an arrangement in a scheme that would be har-

monious with the progressive advance of the perfecting of tooth forms, for convenience of description. It is to be hoped that this breach will be overlooked, as well as the zoological errors that may have crept into the pages, but which will probably not affect the value of the lessons to be drawn from the main principles.

While this book will furnish the various facts and principles of Comparative Dental Anatomy, it will be necessary for the teacher to enlarge upon and elaborate the subject by the use of the general works of the anatomists and zoologists. It will also be necessary to illustrate the lessons by the use of accessories such as skulls, charts, sketches, and especially the lantern, which is the best of all for illustration in the class-room.

The best place for this branch in the curriculum will be as a preliminary study in the course on Dental Anatomy, preceding and leading up to human dental anatomy. It begins with the lowest forms of life and leads up to the highest in regular gradation,—taking the teeth seriatim from the lowest types, and showing their progressive evolution from simple to complex forms.

A list of questions has been appended to each chapter which will be an aid to the teacher for recitation, as well as for the students in class quiz.

It would be impracticable to append references to authorities in a condensed work of this character, for economy of space; but the writer takes

pleasure in acknowledging his indebtedness to the leading authorities upon odontography and zoology for the many drafts he has made upon the rich stores they have accumulated and placed at the disposal of students and teachers. He wishes also to acknowledge the courtesy of Mr. C. H. Ward, of Ward's Natural History Establishment, Rochester, N. Y., who kindly furnished specimens for most of the illustrations.

A. H. THOMPSON.

TOPEKA, KANSAS, September, 1898.

CONTENTS.

Comparative Dental Anatomy.

CHAPTER I.

GENERAL ZOOLOGY AND COMPARATIVE ANATOMY.

(1) THE *Animal Kingdom* is divided into two sub-kingdoms,—viz, (a) *Invertebrates* and (b) *Vertebrates*. These sub-kingdoms are further subdivided into classes; classes are divided into orders, orders into families, families into genera, and genera into species. Species is the last division into which animals can be classified, but if the individuals of a species vary much from the normal type, they may be classed as sub-species or varieties. All animals are grouped with reference to their plan of structure, and classification is made according to the system of organization, and without regard to superficial characters or resemblances except so far as external features may have reference to functions.

(2) Vertebrates and Invertebrates are distinguished from each other by the presence or absence of a *vertebral column* or *backbone*. The Vertebrates have a cerebro-spinal axis and a strong bony col-

umn composed of separate pieces called vertebræ, which are connected together by ligaments and are more or less movable. The sub-kingdom of the Invertebrates comprises all classes of animals which do not have a vertebral column, whatever their various plans of structure may be. The class of the Vertebrates is therefore homogeneous, and that of the Invertebrates very heterogeneous.

(3) The sub-kingdom of the *Invertebrates* includes all animals which have no internal backbone or vertebral column: such as the *Infusoria, Hydroids, Radiata, Worms, Insecta, Crustacea, Mollusca,* etc.

There is no spinal cord with its anterior enlargement, the brain, in the Invertebrates, but instead the nervous system consists of chains of ganglia scattered throughout the system, arranged in rows or circles connected by cords of nervous substance and giving out filaments to various parts of the organism.

The digestive system is simple. The stomach may be a single sac with but one opening (as in the Hydroids), or a complete alimentary canal with two openings,—the oral and anal,—as in the worms, insects, mollusks, etc. In the lower forms specialized digestive glands do not appear, but are present in the higher orders.

The circulation is a mere water vascular system in the lowest aquatic forms, in which there is no corpusculated or true blood, and no circulatory

organs. In the higher Invertebrates there is true blood, colorless or greenish, with true veins and arteries. In the insects there is a distinct heart with one ventricle. In the mollusca there is a heart with one valve which propels the blood both ways alternately. Some forms have a bilocular heart.

Respiration is performed in the lowest forms by tentacles or cilia, and the higher aquatic forms have cilia or gills. In the insects the blood is aërated by circulation of the air in the pulmonary tubes which ramify throughout the body. The snails breathe by means of an air-sac with a ciliated lining.

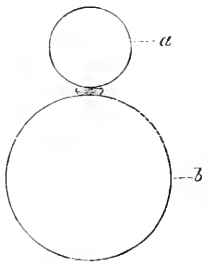
Locomotion is performed by various means: by tentacles and cilia in the lower forms; by legs and wings in the insects; by legs in the crustacea; by a fleshy peduncle in the mollusca, etc.

Reproduction is performed by fission, budding, etc., in the lowest forms; the laying of gelatinous eggs in the higher orders, etc. Some forms, as the insects, undergo a series of metamorphoses before attaining the mature stage.

(4) The sub-kingdom of the *Vertebrates* comprises all animals which have an internal backbone or vertebral column composed of articulated vertebræ. It includes the *Fishes, Reptiles, Birds*, and *Mammals*. From the vertebral column the limbs are suspended, and by it the vital organs are held in place. It is the central structure and mainstay of the framework of the body.

A transverse section of a vertebrate body reveals two cavities or tubes, which are separated by the vertebral column. The upper cavity or canal, which is formed by the arches of the vertebræ, contains the spinal cord and brain, and so is called the *neural arch* or cavity. The lower and larger cavity or tube is below the vertebral column, is formed by the ribs and abdominal walls, and contains the vital organs, the viscera. Hence it is called the *visceral arch* or cavity.

FIG. 1.



SECTION OF VERTEBRATE.
a, The neural arch; *b*, The visceral arch.

The nervous system of Vertebrates consists of the spinal cord and its expanded portion, the brain, which is contained in the neural arches of the vertebræ,—the brain-case being but modified vertebra. Nerve branches and filaments are sent from the cerebro-spinal axis to all portions of the body. Many of the lower forms of Vertebrates, as the *Amphioxus*, have no bony spinal column, but only a cartilaginous structure; but the spinal cord is

present, looking like the notochord of the embryos of all Vertebrates in the first stages of existence.

The alimentary canal has its beginning at the oral opening, the mouth, which is armed by teeth of a great variety of forms in the Fishes, Reptiles, and Mammals for the reduction of food preparatory to digestion. There is a digestive stomach and an intestinal canal, which is more or less complicated in the different classes, that leads to the anal opening at the posterior extremity of the organism.

The circulation is complete in all forms of Vertebrates. The blood is corpusculated, and is generally red in color. The heart has from two to four chambers.

Respiration is performed by gills in the Fishes, by gills and lungs in Reptiles, and by lungs only in the Birds and Mammals.

The external covering in this sub-kingdom presents a great variety of forms. In the Fishes and Reptiles the skin is bare or is protected by scales or spines of great variety. In Mammals there is a tough, leathery skin or dermal plates, or fur, hair, or bristles. The Birds are covered with feathers, which on the wings and tail are enlarged and modified to assist in the performance of aërial flight. The limbs in the Vertebrates are suspended from the vertebral column, and constitute the appendicular skeleton. There are never more than four, sometimes they are reduced to two, and in the snakes are absent entirely When present they are

modified to perform a variety of functions: such as swimming in the water, flying in the air, running upon the ground, climbing trees, seizing objects, etc.

Reproduction is performed by laying gelatinous eggs by the fishes and batrachian reptiles, by eggs with a more or less hard shell in the higher reptiles and birds,—hence oviparous,—and by the young being born alive in some reptiles and nearly all mammals,—hence viviparous.

(5) *Comparative Anatomy* is the study and comparison of the anatomy of lower animals with the anatomy of Man.

The comparative method in study is the only scientific method, for one branch cannot be studied alone, but must be illuminated by comparison with kindred branches. Man is but an insignificant part of nature, and is connected in the closest way with the animal kingdom. His body is identical with those of animals in its functions, and with all Vertebrates, especially mammals, in its structure. Therefore his anatomy can only become truly scientific through comparative anatomy, and his physiology through comparative physiology. The structure and functions of his organs are only to be fully understood by comparison with those of lower animals.

(6) The leading principles of comparative study are *Homology* and *Analogy*. In biology those organs or parts in different animals are said to be

analogous which, however different their origin, have a general similarity of form and especially of function, while those are called *Homologous* which, however different their general appearance and however various their functions, are but modifications of the same part altered for different purposes. For example, the wing of a bird and the wing of a butterfly are analogous organs, for they look somewhat alike and have the same function,—flying,—but they are not homologous, for they are not the same in structure and are dissimilar in origin. But the forelimbs of all Vertebrates, whether the forepaws of a reptile or a mammal, the wings of a bird or a bat, the arm of a man, the flipper of a whale,—though so different in form and function,—are homologous parts. They have the same general structure, are composed of the same pieces, and undoubtedly have the same origin; they are but modifications of the same structure for different functions. They are homologous but not analogous parts. Again, the lungs of a mammal and the gills of a fish are analogous organs, since they have the same function,—the aëration of the blood,—but they are not the same organs. Therefore Homology has reference to community of origin, and Analogy to similarity of function only.

(7) *Comparative Dental Anatomy* is the study of the teeth of lower animals. The observation and comparison of their forms and functions will illustrate the understanding of the human teeth, be-

cause the teeth of man can only be studied scientifically by comparison with lower forms of the same organs,—just as in studying other organs, by the comparative method. Thus homologies with the teeth of lower forms can be demonstrated, and analogous structures in other locations will throw light upon their variations, by these studies. This will illustrate the principles which have controlled their growth and organization, and explain the varied details of function.

(8) The *teeth of man* have, in the course of their evolution to present forms, passed through the transitional stages common to all organs in all animals. In consequence they, like other organs, still retain many features that indicate relationship with the teeth of lower animals. The teeth of man have been much reduced in size and strength, and are more or less rudimentary and much less specialized, as compared with the highly developed teeth of other animals. Comparative study will therefore point out the relationship of the teeth of man, indicate the path of their development, and explain the causes of their present degradation.

QUESTIONS TO CHAPTER I.

(1) What are the two main divisions of the Animal Kingdom? What further divisions are animals classified into? What is a species? What is the proper basis of classification?

(2) How are Vertebrates and Invertebrates distinguished from each other? What is the vertebral column? What kind of animals are Vertebrates? What sub-kingdom is homogeneous? What kind of animals are Invertebrates? Which is heterogeneous?

(3) What animals do the Invertebrates include? Have they a spinal cord like Vertebrates? How is the nervous system arranged? The digestive system? The circulatory? How is respiration performed? Locomotion? Reproduction?

(4) What is a Vertebrate? What four great classes of animals does this sub-kingdom include? What two great arches or cavities does a section of a Vertebrate disclose? What does the neural arch contain? The visceral? What is the nervous system of Vertebrates? What is this like in the lowest forms? What is the digestive system? The circulatory system? The respiratory? What are the various external coverings in these various classes of Vertebrates? What are the various forms of the appendicular skeletons of Vertebrates, and how is locomotion variously performed? How is reproduction performed?

(5) What is Comparative Anatomy? What is the comparative method? How is man related to the rest of the animal kingdom? How, then, can his organs and functions best be studied?

(6) What are the two leading principles of Comparative Anatomy? What is Homology? Analogy? Give examples of homologous organs. Of analogous organs.

(7) What is Comparative Dental Anatomy? How will it illustrate the human teeth? How is the comparative method to be applied in the study of the teeth? How are homologous and analogous structures to be compared?

(8) How have the teeth of man been developed? Have they passed through transitional stages like other organs? Do they retain features indicating their relationship with lower forms? Have they been much reduced in size, strength, and specialization? How will comparative dental anatomy illustrate these things?

CHAPTER II.

THE TEETH IN GENERAL.

(1) *Definition.* The term teeth is applied to all hard, usually calcified substances placed at the orifice of the alimentary canal. They are generally confined to the cavity of the mouth, but are sometimes found in the pharynx and rarely in the œsophagus. The name is, however, confined to those structures located in the oral cavity which contain a calcified tissue known as dentin.

(2) *Origin.* The teeth of animals are derived from the layers of the skin, and hence are but specialized dermal structures. In the Invertebrates they are evolved from the superficial layers of the derm, and are therefore called *ectoderonic*, while the teeth of Vertebrates are derived from the deeper portions, the corium of the integument, and are hence called *endoderonic*. The dentin is a submucous tissue, but the enamel in the higher forms is an epithelial structure, which is readily demonstrated by its histological elements.

(3) *Tissues.* The dental tissues are three in number,—*enamel*, *dentin*, and *cementum*. The cementum is a mere osseous tissue, and in all of its elements resembles true bone. It surrounds the roots of the teeth and is in contact with the alveolo-dental periosteum. The dentin constitutes

the main body of the tooth, and is but modified bone as to its histological elements. It has the same organic basis as bone,—*i.e.*, gluten. In many lower forms it is the only tissue of the tooth, the enamel not being yet organized. In the higher forms the enamel is the main working element of the tooth, for which the other tissues are mere supports. It appears to have been developed by the demand for a more resisting structure as the function of mastication became more specialized. It is developed from the epithelium, and consists of transformed calcified epithelium cells, with the organic basis keratin, like horn, nails, hairs, and other epithelial structures.

(4) *Functions of the Teeth.* The main function of the teeth throughout the animal kingdom is the seizing and reduction of food substances to prepare them for digestion and assimilation. The teeth often perform secondary offices in many animals, but their primary function is the preparation of food for digestion. For this purpose they were called into existence, and by this function they have been infinitely modified. The first act in the performance of this function is *prehension*, or the seizing of food substance; the second is *division*, including cutting into pieces; the third is *mastication*, crushing and comminution into small particles; the fourth is *insalivation*, mixing of the salivary secretions with the food, which is essential to the digestion of some substances, especially starchy foods.

(5) The *food-reducing mechanism* of animals presents great variety when viewed throughout the entire animal kingdom. In no set of organs is the invention of nature so varied or the capacity for change so great as in the teeth. This variation is due to the modifying influences of the qualities of the various substances employed by animals for food, for the teeth and jaws are adapted to the particular manner of reduction that the food of each species requires. It is an adaptation of tools to material, not of material to tools. Therefore there has arisen, in response to the demands of food selection, a great variety of forms of teeth. The different kinds of food have dictated the different kinds of tooth forms.

(6) The *force that dictates tooth forms* is the occlusion of the jaws, with its various vertical and horizontal movements. This force is very great for so small an area. The jaw movements present great variety, and the jaws and teeth are adapted to these movements. Thus in the carnivorous animals there is but one movement, the vertical, and in consequence the temporo-maxillary articulation is a mere hinge, admitting of mere opening and closing of the jaw, without any lateral movement. The jaw is short and stout to sustain the force of hard biting, and the teeth are developed vertically, with long points and blades, in the direction of the resistance to the greatest strain. In the other extreme form—the Herbivorous mammalia—the

articulation is flat and open to allow of extreme lateral movement of the jaw. The jaw-bones are light and the teeth are enlarged laterally in resistance to lateral strain, the grinding faces being made rough by a special arrangement of the dental tissues to render them more effective for the reduction of resisting vegetable substances. Or, again, in the elephant, for instance, the antero-posterior movement of the jaw has caused the arrangement of the dental tissues in transverse plates to resist this movement. So in all animals the forms of the teeth are due to the jaw movements with reference to the resistance of the direction of greatest strain.

(7) *Tooth Forms.* The original and primitive form of tooth is that of the single, simple cone, as illustrated in the teeth of fishes and reptiles, which are simple cones with but little modification. From this primitive form all other forms have been derived by modification and duplications of the single cone. Thus the incisors of man are formed of a single cone, the base of which is compressed to form the wide cutting edge. The canine is a single cone, the base of which is compressed into a trihedral, pointed prism. The bicuspids are formed of two cones fused together,—the bases rounded to make the cusps,—and the two cones are distinct the entire length of the tooth. The typical upper molar is formed by the coalescence of three cones, which are plainly marked, and the lower molar of

four cones. Thus the teeth of all animals, even the highly complex and specialized teeth of the higher mammals, are evolved. As Cope says, "The transition from single to complex teeth is accomplished by repetition of the simple cone in various directions. First, there are cylindrical incisors, then flat ones, then divided roots; then internal repetition of a root and cusp; then posterior repetition. Very complex teeth, as multitubercular molars, are formed by both posterior and lateral repetition." Thus the primitive form of tooth is that of a simple cone, from which all subsequent forms, however complex, have been derived by repetition, duplication, and modification of cones and cusps.

(8) *Nomenclature.* The following list of terms with definitions has been proposed and adopted by the American Dental Association for use by the profession in dental anatomy:

Acrodont. Having teeth ankylosed on parapets of bone on the edges of the jaw (as found in some lizards).

Alveolar. Pertaining to the alveoli or sockets of the teeth; as, alveolar arch, alveolar border.

Alveolus (Pl. *Alveoli*). The socket of a tooth.

Anisognathous. Having the upper molars unlike the lower in size and pattern.

Ankylosis. The growing together of two bones or parts of bones. Applied to the union of teeth to the jaw-bone.

Arch. The curve made by the upper and lower teeth.

"*Aristotle's Lantern.*" The dental apparatus of *Echinus.*

Asymmetry. Absence of symmetry.

Axial. Term applied to all surfaces, walls, and lines parallel to the long axis of a tooth.

Basal. Of, pertaining to, situated at, or forming the base.

Bell-crowned. Applied to a tooth crown which is largest at the occlusal surface and tapers toward the cervix.

Bicuspid. The premolar of man (a tooth with two cusps).

Bifurcated. Divided in two in fork form, as the roots of the inferior first and second molars, or in many cases of the superior first bicuspid of man.

Brachycephalic. Having a skull the transverse diameter of which is more than eight-tenths of its long diameter.

Buccal. Toward the cheek.

Bunodont. Tooth crown supporting tubercles.

Calcareous. Composed of or containing lime.

Canine. The first tooth posterior to the intermaxillary suture above and its opponent below.

Canine Cusp. The buccal cusp of the bicuspid.

Caniniform. Formed like a canine,—long, slender, and pointed.

Cementum. A tissue resembling bone which covers the outer surface of the roots of teeth.

Cervical. Of or pertaining to, a neck. Applied to that portion of the tooth where the enamel and cementum unite.

Cervix. The neck of the tooth, the portion grasped by the gum,—between the crown and root.

Chitin. The horny covering of insects and Arthropoda, of which the masticating apparatus of the Invertebrates is often composed.

Cingule. A small cusp or tubercle, usually on the lingual face of a tooth.

Cingulum. The ridge or tubercle on the lingual face of a tooth near the gum.

Coalescence. The structural union of like parts, as the coalescence of the roots of a tooth.

Complex Crown. A tooth crown composed of two cones (as the bicuspids) or of three or more cones (as the molars).

Cone. The mechanical element of the tooth crown.

Cone-shape. Teeth formed of one cone only,—as the teeth of fishes and reptiles and the canines of mammals.

Coronal. Of or pertaining to a crown. Applied by some to the occlusal surfaces of teeth.

Coronoid. Having a crown-like form.

Crests. The sinuous cusps or enamel ridges on the grinding faces of the molars of Herbivora.

Crown. That portion of the tooth which is exposed above the gum.

Crucial. Having the form of a cross.

Cusp. A sharp eminence on the occlusal surface of a tooth crown.

Cuspid. A tooth with one point or cusp,—the canine.

Cuspidate. Formed of or like one or more cusps.

Deciduous. Liable to be shed at periodical or certain stages of growth; as antlers, hair, teeth. Applied to the first series of teeth of young mammals, which are replaced by the permanent set.

Dens Sapientiæ. The third molar, the wisdom-tooth of man.

Dental. Referring or pertaining to the teeth.

Denticles. Shapeless calcareous bodies which serve the purposes of teeth.

Denticulate. Furnished with small teeth.

Dentigerous. Bearing or supporting teeth,—supplied with teeth; also containing teeth, as a dentigerous cyst.

Dentin. The calcified tissue that forms the main portion of the teeth.

Dentinal. Referring to the dentin.

Dentinoid. Having the form of a tooth.

Dentition. The eruption of the teeth.

Deuterocone. The mesio-buccal cone of the upper premolar.

Deuteroconid. The mesio-buccal cone of the lower premolar.

Diastema. A space between the teeth,—especially the space between the upper lateral and canine into which the lower canine closes in the Carnivora, Quadrumana, etc.

Diphyodont. An animal having two sets of teeth, both the deciduous and the permanent.

Distal. Away from the median line of the face (following the curves of the dental arch).

Docoglossa. Plate or chevron formed teeth of mollusks.

Dolichocephalic. Having a long skull, the breadth being less than 75% of its length.

Ectodermic. Applied to structures derived from the upper epithelial layers of the derm, as hair, chitin, enamel, etc.

Elastic Hinge. A device found in fishes and reptiles, by which the teeth can be pushed over and then sprung back to hold prey.

Enamel. The calcified epithelial tissue covering the crowns of teeth.

Endodermic. Applied to structures derived from the lower layers of the derm, as dentin.

Entoconid. The linguo-distal cone or cusp of the posterior heel or talon of the lower molars.

Epithelium. The superficial layer of cells of mucous membranes. A very delicate membrane forming the outer covering of the corium or true mucous membrane, and which enters into the structure of glandular organs.

Fang. The root of a tooth.

Fibrous Membrane. The membrane which carries the teeth of sharks and rays.

Foramen. A passage perforating tissues (usually bone) and transmitting vessels or nerves; *e.g.*, the apical foramen of the root of a tooth.

Fossa. A round or angular, shallow depression in the occlusal surface of bicuspids and molars, and the lingual surface of incisors and canines.

Ginglymoid. Hinged, as the jaw articulation of the Carnivora.

Gluten. The organic basis of bone, dentin, etc.

Gomphosis. Attachment of the teeth by implantation in a bony socket or alveolus.

Gothic (arch). Of or pertaining to the pointed types of mediæval architecture, as Gothic arch. Applied to teeth arranged in a Gothic arch.

Haplodont. Having undivided or simple tooth crowns.

Heterodont. The teeth being of heterogeneous or unlike forms in the same jaw.

Homodont. The teeth being of homogeneous or similar forms throughout the same jaw.

Hypocone. The linguo-distal cone of the upper molars.

Hypoconid. The disto-buccal cone (or cusp) of the lower molars.

Hypoconulid. The distal cusp—the fifth tubercle —of the lower molar.

Incisor. A tooth with a cutting edge,—from incise, to cut. The anterior teeth above located in the intermaxillary bones (whatever their shape), and their opponents below in the anterior portion of the lower jaw.

Isognathous. Having upper and lower molars of same size and pattern.

Kreatin (or *Creatin*). The organic, epithelial basis of horn, hair, enamel, etc.

Labial. Pertaining to or toward the lips.

Lateral (incisor). The second incisor from the median line.

Lenticular Jaws. The serrated maxillæ of the leech and other worms.

Lingual. Situated near or toward the tongue, as the lingual surface of a tooth.

Lobe. A division of a tooth crown formed from a distinct point of calcification.

Lophodont. Summit of a tooth crown thrown into transverse or longitudinal folds.

Macrodont. Having large teeth.

Mandible. The lower jaw.

Mastax. The muscular pharynx of a rotifer, containing the jaw parts.

Mastication. The process of comminuting the food with the teeth—synchronous with insalivation.

Maxilla (Pl. *Maxillæ*). The upper jaw or jawbone.

Maxillary. Of or pertaining to a jaw or jawbone.

Median. Middle, as the median line of the body.

Mesial. Toward the median line of the face (following the curve of the dental arch).

Mesocephalic. A term applied to a skull having a capacity between 135 and 145 c.c.

Mesodont. Having medium sized teeth.

Mesognathous. Having a moderate or intermediate gnathic index of from 98 to 103—as a skull.

Metacone. The disto-buccal cone (or cusp) of the upper molars.

Metaconid. The mesio-lingual cone (or cusp) of the lower molars.

Microdont. Applied to small-toothed races.

Molar. A grinding tooth with multi-cusped crowns.

Monophyodont. An animal having but one set of teeth, *i.e.*, the first set not being shed, but remaining permanently.

Multitubercular. A tooth crown having many tubercles.

Neck. The narrowest part of an object; the junction of crown and root of a tooth.

Oblique Ridge. The ridge running obliquely across the occlusal surface of upper molars, from the mesio-lingual tubercle to the disto-buccal. (It is the marginal ridge of the primitive tritubercular molar.)

Occlude. To strike against, as the articulation of the upper with the lower teeth.

Occlusal. Applied to the grinding surface of the teeth.

Odontogeny. The generation or origin and development of the teeth.

Odontography. A description of the teeth.

Odontophore. The strap-like organ of mollusks which carries the teeth.

Orthognathism. Having perpendicular facial lines, *i.e.*, near 90°; as, the European races.

Paracone. The mesio-buccal cone (or cusp) of the upper molars.

Paraconid. The mesio-lingual cone (or tubercle) of the lower molars, which has been lost in man and some other mammals.

Permanent Teeth. Those teeth which appear in childhood and are retained as the teeth of adult age.

Placoid. Plate-like, as the scales and some kinds of teeth of sharks and rays.

Pleural. Pertaining to a pleuron or lateral part. Applied to the lateral rows of teeth on the odontophore.

Pleurodont. Having teeth attached by ankylosis to the sides of the dental groove, as in some reptiles.

Premolars. The succedaneous grinders between the canines and true molars in mammals (called bicuspids in man).

Prognathism. A projecting lower jaw, and a facial angle below 75°.

Protocone. The primitive reptilian cone of an upper molar, *i.e.*, mesio-lingual cusp; also the buccal cusp or cone of an upper bicuspid or premolar, etc.

Protoconid. The mesio-buccal cone (or cusp) of a lower molar; also the mesio-buccal cone of a lower premolar.

Ptenoglossa. A group of gasteropods having teeth only on the sides of the odontophore, but no middle row.

Ptychodont. Tooth crowns folded on the sides, sometimes across the crown.

Pulp. The soft tissue of vessels and nerves which fills the pulp-chambers and root-canals of a tooth; the remnant of the formative pulp.

Pulp-canal. That portion of the pulp-cavity traversing the roots of teeth from the apical foramina to the bottom of the pulp-chambers.

Quadritubercular. Teeth having four tubercles.

Quinquetubercular. Teeth having five tubercles.

Rachidian. Pertaining to the rachis or axis. Applied to the central rows of teeth on the odontophore.

Radula. The dentary organ of mollusks.

Raphidio-glossa. Needle-shaped teeth on the odontophore.

Ridge. A long elevation on the surface of a tooth crown.

Root. That portion of the tooth which is inserted in the alveolar process.

Root-canal. A canal in the center of the long axis of the root which contains the branches of the pulp.

Rugæ. Folds or creases. Applied to the irregular ridges of the membrane of the roof of the mouth.

Scalpriform Incisors. The cutting incisors of the rodents and other mammals.

Sectorial Teeth. The cutting teeth of the Carnivora, the long-bladed premolars and molars.

Selenodont. Having longitudinal crescent-shaped ridges, as a molar tooth.

Septum. A partition of the alveolar process which separates the alveoli.

Stomacholiths. The calcareous plates found in the stomach or gizzard of crustaceans, which carry cusped or molar-like eminences.

Succedaneous. Those teeth of the permanent set which succeed or take the places of the temporary teeth.

Sulcus (Pl. *Sulci.*) A long, narrow channel, or furrow; a groove. Applied to narrow depressions and grooves on the surfaces of teeth.

Supernumerary. Having more than the usual or normal number.

Symphysis. The coalescence or junction of bones, usually of symmetrical bones in the median line.

Tænio-glossa. A kind of gastropod having bent teeth on the odontophore.

Talon. The linguo-posterior prominence or heel of an upper molar crown, bearing the hypocone.

Talonid. The heel, or disto-buccal portion, of a lower molar crown, bearing the entoconid, hypoconid, and hypoconulid.

Tetartocone. The linguo-internal cone; the fourth cusp of the upper premolar.

Tetartoconid. The linguo-internal cone of the lower premolar.

Theca. Pertaining to a sheath or case.

Thecodont. Having fangless teeth, as a lizard.

Tooth (Pl. *Teeth*). A specialized dermal structure, situated in the oral cavity, containing a calcified osseous tissue called dentin.

Toxoglossa. Mollusks having arrow-shaped teeth.

Transverse Ridge. A ridge extending across the crown of a molar.

Triangular Ridge. The ridge running down from the point of a cusp or tubercle toward the center of the crown.

Triconodont. Having three cones in a line.

Trigon. A triangle. Applied to the first three cones of an upper molar.

Trigonid. The first three cones of a lower molar.

Trigonodont. A tooth having three cones in a triangle.

Tritocone. The mesio-buccal cone of the upper premolars.

Tritubercular. Having three tubercles upon the occlusal surface.

Truncate. Cut off or terminated abruptly.

Tubercle. A small rounded eminence on the occlusal surface of a molar; a cusp.

Tusk. A prominent incisor or canine which protrudes some distance beyond the lips.

Ulcini. The external teeth on the odontophore.

QUESTIONS TO CHAPTER II.

(1) What is the definition of the term teeth? Where placed? What principal tissue must teeth always contain?

(2) From what tissue do teeth originate? Hence what kind of structure are they? From what layer of the skin are they derived in Invertebrates? Hence are called what? Why ectodermic? From what layer are the teeth of Vertebrates derived? Hence named what? Why endodermic?

(3) What are the main tissues of the teeth? What is the nature of cementum? Where is it found? The dentin—and where found? The enamel—and where found? Which is the primary original tissue in lower forms? What does the enamel bear in relation to the work of the teeth?

(4) What are the functions of the teeth? What has function had to do with their origin and development? What is the first act in food reduction? The second? The third? The fourth?

(5) What is the food-reducing mechanism in animals? To what is the great variety of forms of dental apparatus due? What is food selection? How is adaptation to food brought about? Is it all-powerful?

(6) What is the force that dictates tooth forms? Is jaw-force in occlusion very great? What varieties of jaw movement are there in carnivorous and in herbivorous animals? How are the jaws and the articulation shaped to be adapted to these movements? Describe the carnivorous jaw; the herbivorous. Have these movements dictated jaw forms, and also tooth forms?

(7) What is the primitive and original form of tooth? In what animal is the cone shape first found? How is this form modified in the fishes and reptiles? How were complex teeth derived from the simple cone? How was modification and duplication accomplished? How was the incisor of man formed from a single cone? The canine? How was the bicuspid formed from two cones? The molar from three cones? How was the simple cone repeated in various directions? How by posterior and lateral repetition?

(8) Ask the definition of terms from the list.

CHAPTER III.

THE TEETH OF INVERTEBRATES.

(1) The teeth of this sub-kingdom present as many variations and extraordinary forms as the organic designs of the heterogeneous mass of animals composing this great division. Not many of these lower forms possess teeth, but when present the form presented and the analogies suggested are very instructive. They are analogous to the teeth of Vertebrates, as the teeth are usually oral organs in the Invertebrates and perform the same functions as in the higher sub-kingdom,—*i.e.*, the prehension and reduction of food, preparatory to digestion; but they are not homologous with the teeth of Vertebrates, however, as they do not have the same origin or structure. Almost every group, in some of its forms, exhibits some sort of a dental apparatus for the reduction of food, though few are homologous with true teeth. Most of the lower forms are without a masticating armature.

(2) *Origin.* The food-reducing mechanism of Invertebrates, whether oral organs or modified limbs, is composed of calcified connective tissue or of chitin, and is derived from the superficial layer of the derm. They are therefore *ectodermic*. In insects and crustaceans the food apparatus is modified from the chitinoid external covering.

(3) The *forms* of the food apparatus present great and heterogeneous variety in this division. The so-called teeth of Invertebrates are often but serrated jaws placed about the oral opening. The margin of the mouth may be raised into folds and armed with cuticular plates. In the insects and crustacea the jaws and modified limbs are formed from the exo-skeleton. In some—as the cuttle-fish—there is a strong beak. In the Sea-urchin there are five teeth set in true alveoli. In the mollusks the teeth are supported by a movable band, called the odontophore.

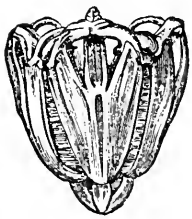
(4) *Functions.* Prehension is performed in this sub-kingdom by cilia in many of the lower forms, in the worms and gastropods by a suctorial form of the mouth, in others by tentacles, and in insects by their chitinoid jaws and modified limbs. Cutting and dividing food is performed by jaws and mastication by gizzards, when performed at all. No true masticating teeth exist in the entire sub-kingdom. Some have the food apparatus developed for purposes of combat or sexual attraction, some for drilling through shells to get the juices of the animal within, or even to drill into rock.

(5) *Descriptive.* All of the lowest forms, infusoria, etc., are without any food-reducing apparatus, except some which have an internal cylinder of parallel rods for the crushing of food. In the Rotifera oral denticles are present in the shape of denticulated plates placed transversely of the

mouth, which crush and comminute the food, which is principally infusoria.

In the *Echinoderms* we meet with the Sea-urchin, which has a highly developed and effective dental apparatus of complicated mechanism. It is very remarkable to find this highly organized apparatus at this low stage of animal life, for it is one of the most wonderful dental structures in the entire animal kingdom. It is popularly called "Aristotle's Lantern." It consists of five rodent-like incisors

FIG. 2.



Dental Apparatus of Sea-Urchin (Aristotle's Lantern).

of continuous growth, arranged in the form of a pyramid, with their points centering and finding exit in the middle of the test. These teeth are hard and calcareous, with the enamel thicker on one side than on the other, so as to insure continued sharpness from wear. They are set in alveoli of bony structure, and are moved by sets of strong muscles in various directions. The entire apparatus consists of twenty pieces,—*i.e.*, five teeth, five alveoli, five rotalæ, and five radii. It is concealed within the test in life with only the points of the

teeth projecting, which are very effective for cutting shells, boring into rocks, and reducing food-substances.

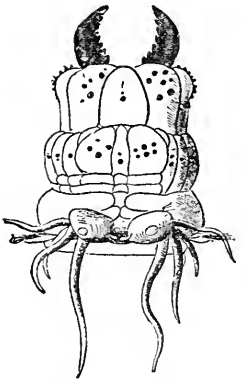
The *Annuloida* comprise the segmented worms, some of which possess so-called teeth, but these partake more of the nature of serrated jaws than of teeth. These jaws are located on the second or buccal segment, which may be protruded from the mouth a considerable distance. These jaws are of chitinous structure, commonly paired and of an infinite variety of forms. In the Leeches the mouth is provided with three lenticular jaws, with the projecting edges finely serrated. The medicinal leech has two rows of serrations, which make three radiating slits. The strong suctorial power draws an eminence of skin into the mouth, which is slit by the serrated jaws.

The *Nereis* and *Philodace* have strong jaws like the carnivorous beetles, which are cruelly effective in attacking lower Invertebrates. Their jaws are serrated and opposite, and are worked by powerful muscles.

In the *Arthropoda*—including the Insects and Crustacea—we have an approach to true jaws, but they work laterally instead of vertically, as in the Vertebrates. The mandible and maxillæ are very dense chitinous material, and the "teeth" are merely serrations on the edges. In the insects one pair of each—mandibles and maxillæ—make four jaws, which work transversely in addition to the

labia, which merely cover the mouth. These organs are modified in endless variety for various purposes,—from strong jaws for cutting purposes to the long suctorial tubes of the butterflies. The so-called dental plates lining the crops of insects and crustacea further comminute the food, and hairs keep the larger particles back until finely crushed. In the lobsters, crabs, etc., the "pinch-

FIG. 3.



Head and Jaws of *Nereis virens*.

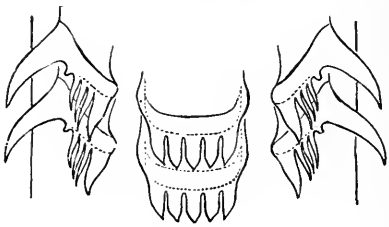
ers" are but modifications of the limbs translated from the locomotive series and set apart for special mouth organs. In the higher crustaceans the stomach is provided with calcareous plates or stomacholiths, with molar-like prominences for grinding food by means of the powerful muscles which move them. These are interesting structures, as they show how similar functions may de-

velop analogous structures in dissimilar parts which have no homology whatever.

In the *Mollusca* we find that the bivalves (the clams, oysters, mussels, etc.) are entirely without head or dental apparatus. The other groups, however, present some form of dental structure in most of their members. In the Cephalopoda the organs of mastication include a corneous beak, resembling that of a parrot, but reversed; within

FIG. 4.

Radula of Winkle.



Two Rows of Teeth, enlarged.

the oral opening there is a fleshy tongue, which is armed with many transverse rows of recurved, spinous teeth. This is called the odontophore. This organ is controlled and moved by powerful muscles which draw it backward or forward, or even protrude it, as in the snail. The teeth vary greatly in number in the many various species. Thus the nautilus may have but thirteen, and the snail 12,000 to 40,000. As the teeth are worn off or lost, the ribbon-like tongue is uncoiled

and new teeth are brought into use. The upper part of the mouth is usually lined with a horny substance, against which the sharp-toothed tongue works with a rasp-like motion. The teeth vary in form, but are usually composed of a base, a shank or stem, and a cutting edge, the latter simple or variously denticulated. The middle row of teeth is called the rachidian; the lateral rows, the pleural teeth, and when an additional row occurs outside of this it is called the uncini. The highest type of these molluscan teeth is called the Toxoglossal, or arrow-tooth, from its narrow, round form, often barbed, sometimes hollow to inject poison. They have but two rows,—the middle or rachidian being absent. The Rachiglossa have only the middle row, or rachidian teeth. The teeth are slight and varied in form, and prettily denticulated on the cutting edge. They are few in number. The Ptenoglossa, feather-toothed, is a small group. They lack the middle rows, but have numerous small teeth on the side of the tongue. The Docoglossa, chevron-toothed, is a large group, and presents considerable variation among its members as to the presence or absence of the different rows of teeth. The Raphidoglossa, needle-toothed, have large numbers of uncini teeth, the other rows varying in different groups. They usually have a well-developed mandible, or jaw, which is hinged in the middle. The Tænioglossa, bent-toothed, includes the greater number of the fresh-water snails. The

teeth vary in number and are often absent entirely. The common Helix, or air-breathing snails, often present a pavement-like form and arrangement of the teeth, which are often of a very pretty pattern, or, again, are a mere hardened mass. The lingual ribbon, beset with such teeth, is well adapted for filing off or rasping food and drawing it backward into the mouth. Besides that use it is also employed by some sea mollusks in boring into shells to abstract the juices of the animal within.

QUESTIONS TO CHAPTER III.

(1) What is the second great sub-kingdom of animals? Are the teeth of this branch very heterogeneous? Are any low forms without teeth? Are the teeth, when present, analogous or homologous with the teeth of Vertebrates? Why analogous? Why not homologous?

(2) From what layer of the skin are the teeth of Invertebrates derived? Hence are called what? Of what material are they mainly composed?

(3) Do the forms of the teeth vary greatly in this branch? Name some of the forms in the worms. The crustacea. The cuttle-fish. The sea-urchin. The mollusks.

(4) What is the main function of the teeth in this sub-kingdom? How is prehension performed in the different classes? Are masticating teeth proper well developed? What secondary offices are often performed by the teeth in Invertebrates?

(5) What forms of teeth are found in the lowest types, as the Rotifera? What sort of a dental apparatus is found in the sea-urchin? Is it highly organized? How many pieces is it composed of? Name them. What is the structure of the teeth? Are they set in true alveoli? Do they grow contin-

ually? For what are the teeth used? What kind of teeth or jaws are found in the worms? In the Leech? How are they used? In Nereis?

(6) What is the masticating apparatus in the Insects? In the Crustacea? How is mastication performed in these classes? How are the stomacholiths of lobsters and crabs analogous with the grinding teeth of Vertebrates?

What group of the Mollusca possess teeth? What do not? What class possess a beak? What organ in the mollusks carries the teeth? Where is it located? How is it moved? How do the teeth vary as to number? How do they vary as to shape? What is the middle row called? The lateral rows? The outside rows? What sort of teeth have the Toxoglossal Mollusca? The Rachiglossa? The Ptenoglossa? The Docoglossa? The Raphidoglossa? The Tænioglossa? Describe the teeth of the common snail. How is the lingual ribbon or odontophore used by the snails?

CHAPTER IV.

THE TEETH OF VERTEBRATES.

(1) In this great sub-kingdom true teeth are the rule and not the exception. They are enderonic structures, because derived from the deeper portions of the derm, or corium of the integument, and possess a calcified tissue called *dentin*. This is the main tissue of the teeth in all Vertebrates, but in the higher forms the crown is covered and protected by a calcified epithelial tissue called *enamel*, and the root is surrounded by an osseous tissue known as *cementum*. The teeth of the lower Vertebrates, the Fishes and Reptiles, are composed mainly of dentin, and to this the other tissues, enamel and cementum, are added in the higher forms.

(2) In *position* the teeth in the Vertebrates are mostly confined to the oral cavity and to the bones and cartilages of the head and face. In the higher Vertebrates they are supported by the upper and lower jaws,—the maxillæ and mandible only. In the lower forms they may extend to the thorax (or even to the œsophagus, as in some snakes), being supported by various bones and cartilages about the oral cavity.

(3) *The Attachment of the Teeth* in Vertebrates presents four varieties or methods, which grade

into one another in different degrees. These are as follows:

1st. By means of a *Fibrous membrane* (as in the Sharks and Rays), in which the teeth are imbedded, and which carries them up over the edge of the jaws. The teeth are brought up from the floor of the mouth and rise up to replace those which are lost from accident or use.

2d. By *Elastic Hinge* (as in many fishes, the Pike, Cod, etc.). The hinge is composed of strong fibrous ligament. Such teeth yield to pressure as prey passes over them, and then spring up to hold it while struggling.

3d. By *Ankylosis*, when there is no intervening membrane, but the teeth and the jaw-bone are ossified into one continuous piece like an ankylosed joint. Such teeth are sometimes but slightly attached, or, again, so strongly as to bring away a piece of bone when detached. Ankylosed teeth are found in many fishes and reptiles.

4th. *By Implantation in a bony socket*, as found in some Reptiles and in the entire class of the Mammalia. It is the method of attachment in man. There is an intervening membrane, the periosteum, between the root of the tooth and its alveolus, and a special bone of attachment, called the alveolar process, which is raised up around the root to support the tooth as it comes into place, and is absorbed when it is lost.

(4) *Tooth Forms.* The forms of the teeth in

the Vertebrates present great variety. In the lowest classes, the Fishes and Reptiles, the simple conical form predominates, as the teeth in these low types are modifications of the simple cone. This is the primitive typal form of tooth from which all later and complex forms were derived (as described in Chapter II, page 21). There is considerable variation of the cone, however, in these classes, some fishes, as the Rays, etc., having plates or a pavement of teeth of flattened shape. Others are of cylindrical or prism-like outline, but the majority of fishes and reptiles exhibit modifications of the simple cone, which is employed for prehension only.

In the Mammalia there is greater variety and more complex forms of teeth. These are formed by evolution of the primitive typal cone, by duplication and modification of the cone, to form bicuspid, tritubercular, quadritubercular, etc., forms, as of the molars. Teeth are developed from the primitive cone for various functions: thus the incisors are molded from a single cone by flattening of its base, to cut substances; the canine is a single cone elongated and sharpened, to seize and tear flesh; the bicuspids—as in man—are formed by the addition of a second lingual cone to the primitive buccal cone, to crush food, or by the addition of a third cone to form the tritubercular molar, or of the fourth to form the quadritubercular molar, etc., to grind food. There is sometimes special develop-

ment of special teeth for secondary purposes, as of the incisors of the Elephant, Sirenia, Narwhal, etc.; or the canines of the Walrus, the extinct carnivora, the wild boar, etc.; or of the blades of the premolars of the carnivora, etc. The premolar and molar teeth were evidently developed by the duplication of cones by fusion or addition, which are traceable back along the paths of their development through geologic ages, to simple conic reptilian forms. There was first the simple cone alternating with that of the opposite jaw, as in the living reptiles (*Haplodont* form); then the double cone, formed by the addition of a second cone (as the bicuspid of man); then the third cone was added to form the triconodont type, which was modified to the tritubercular form of molar (the primitive type of all molars); then the projecting heel or cingule led to the formation of the fourth tubercle (the *quadritubercular* molar); then the addition of the fifth and other tubercles formed the additional types. Thus the cones were duplicated and tubercles added to form the multitubercular types. These molar tubercles are rounded *(Bunodont)*, as in Man, the Bears, Mastodon, etc.; raised to form cutting blades in the carnivora; or folded and duplicated *(Lophodont)* in the herbivorous mammalia to form broad triturating surfaces, etc.

(5) *The number of the Teeth* in Vertebrates varies greatly in different classes, and may even vary in the same genera. Some fishes are entirely

without teeth of any kind; others have but one (as the Myxine and other parasitic forms), which is used as a lancet to cut the flesh for the purpose of drawing blood; others have a few teeth, and the number increases up to the thousands in the bony fishes, and which may stud the mouth in every conceivable position. These are of continuous succession, so that the numbers are always indefinite. The reptiles have fewer teeth than the fishes, but these succeed one another continuously, and the exact number cannot always be determined. Different individuals of the same species will present great variations. In the mammals the number can be determined with greater precision, as each species, especially of the higher forms, has a definite number. In the lower mammals, as with the reptiles, the number is somewhat indefinite, but with the advance in the scale it becomes more exact. Some species are devoid of teeth entirely, as in some Ant-eaters. Others have but one tooth, as the Narwhal. A Dolphin has but two; the Elephant has but two incisors, and but four molars in use at one time. Some rodents have but two incisors and four molars in each jaw; the Sloths have but eighteen teeth; Man, the old world Monkeys, and some other Mammals have but thirty-two teeth, etc. The number increases in various families to an excessive degree: thus some of the Armadillos have ninety-eight; some Whales sixty; the common Porpoise eighty to ninety; the Gan-

getic Dolphin one hundred and twenty, and the true Dolphin one hundred to two hundred.

While there is thus great variation in the numbers of teeth in the various classes of Vertebrates and even among the members of the same genera and families, there is a rule governing all which renders their study intelligible. This is based on a scientific classification and arrangement by means of which all teeth and tooth forms can be properly understood.

(6) Vertebrate teeth are *classified* into various divisions having references to their forms, position, and functions. In the fishes and reptiles the teeth are adapted mainly for seizing and tearing, and consequently are undifferentiated as to position and function. There is little variety in different parts of the jaw as to the forms of the teeth, but only as to size, and there is not sufficient differentiation to admit of classification. But one function is performed in these low classes, that of prehension, for mastication is not yet developed. In the higher Vertebrates, the Mammalia, however, the teeth are more differentiated and special forms are evolved for special uses. Thus the teeth situated in the front of the oral cavity, from their form, are called *incisors*, or cutters, and their function is to cut or divide food. The large conical teeth situated immediately distally of the incisors are called the *canines* (from being extra well developed in the dog and other carnivorous animals), and are used

for seizing and tearing flesh. The next teeth are the *molars*, the crushers and grinders, which perform the function of mastication and insalivation. These are divided into two classes, the *premolars* and *true molars*. The premolars are the half molars just distally of the canines. These are called the bicuspids in man. After these are the full or true molars, which are the true grinding teeth. Thus the teeth of mammals are classified into four groups,—(1) the *Incisors*, (2) the *Canines*, (3) the *Premolars*, (4) the *Molars*. With this arrangement it is convenient to express in a mathematical scheme the number of the teeth of any mammal by means of what is called the *Dental Formula*. In this scheme the teeth are represented in numbers in the form of fractions,—those of the upper jaw being the numerator and those of the lower jaw the denominator. Thus the dental formula of Man is—

$$\text{i.}\,\frac{2-2}{2-2}\ \text{c.}\,\frac{1-1}{1-1}\ \text{p. m.}\,\frac{2-2}{2-2}\ \text{m.}\,\frac{3-3}{3-3}=32,$$

reading that he has on each side of each jaw 2 incisors, 1 canine, 2 premolars (or bicuspids), and 3 molars,—the initial letter of each class being used for abbreviation. The teeth of many mammals may be expressed in the same way. The deciduous teeth of Man have the formula—

$$\text{i.}\,\frac{2-2}{2-2}\ \text{c.}\,\frac{1-1}{1-1}\ \text{m.}\,\frac{2-2}{2-2}=20,$$

there being no premolars or bicuspids in the de-

ciduous series. The formula of the Elephant is—

$$\text{i.}\frac{1-1}{0-0}\ \text{c.}\frac{0-0}{0-0}\ \text{m.}\frac{6-6}{6-6}=26,$$

or of the Rat,—

$$\text{i.}\frac{1-1}{1-1}\ \text{m.}\frac{3-3}{3-3}=16.$$

The teeth of all mammals may be expressed in the same manner.

Single teeth are described in this system as follows with reference to the upper or lower series: thus the left upper central incisor is noted $\text{i}|^{1}$,—*i.e.*, the first incisor,—to the left of mesial line and above fraction line. The same tooth below would be $\text{i}|_{1}$. The right upper first molar $^{1}\text{m}|$, the lower left second molar $|\text{m}_{2}$, the right upper second premolar 2 pm|, the left lower third molar $|\text{m}^{3}$; the number being distal of the initial letter and the line mesial.

(7) The *classes* of the teeth in Mammals.

The *Incisors* take their name from the office they perform in the function of mastication,—*i.e.*, to *incise*, to cut, but the term is applied to the teeth located in the premaxillary bone anterior to the intermaxillary suture, whatever their form, in mammals. Thus the tusks of the elephant are incisors, although their cutting function is completely aborted and these teeth are employed as tools and weapons only. The function of cutting or dividing food is performed by various organs throughout the animal kingdom. Teeth for this purpose are developed very low in the scale of life,

as the cephalopods have cutting teeth; the sea-urchin has highly specialized incisors; the insects and worms cut by means of the mandibles, jaws, etc. The beaks of turtles and birds are employed as cutting implements, but these are not true teeth. The fishes and reptiles have no true incisors, as the teeth are of simple conical shape and are employed for prehension only. Most of the lower mammals are deficient in regard to cutting teeth, the teeth being all of the molar type for grinding. The higher forms possess well-marked typical incisors. Thus the incisors of the *Herbivora* are well developed for cutting purposes. In the *Carnivora* the incisors are reduced, for the cutting function is usurped by the long blades of the sectorial premolars and molars. In the *Marsupials*, *Insectivora*, *Rodentia*, *Cheiroptera*, and others the incisors are specially developed for special purposes. In the *Quadrumana* they foretell the form of these teeth in man, which they resemble, in whom incisors are formed by the modification of the single cone,—the base being flattened to form a cutting edge.

The *Canines*. This tooth is the first succeeding the incisors, and is immediately distal to the intermaxillary suture. It is implanted in the maxillary bone proper above, and is probably modified from the premolar series. It is called the Canine from being extra well developed in the dog and other carnivorous animals. It is the principal prehensile tooth in mammals, and is therefore first in

function, though second in position in the dental series. It is implanted by a single root, usually, and is modified from a single cone. It is the most primitive type of tooth, being nearest to the cone shape found in the fishes and reptiles in all parts of the jaws. In the mammals it still preserves the primitive form, though modified variously in different classes. The lower mammals have no canines, but the Dolphin and Cetacea have conical canine-like teeth in all positions like the Reptiles. In the Marsupials it begins to assume specialized forms. It is absent in the *Proboscidæ* and *Rodentia* and in some of the *Ruminants*. In some of the Herbivora it is of incisor-like form, and is ranged with these teeth for cutting purposes. It is excessively developed in the Musk-deer, Boar, Walrus, and other animals, for battle or other secondary purposes. But it is in the *Carnivora* that the canine attains its greatest glory. In its monstrous development in some fossil carnivores it extended far beyond the lower jaw, and was of a saber-like form which is recalled in lesser degree in the extinct Cave Tiger and the Lion and Tiger of today, which have the posterior edges of this tooth serrated. In the *Felidæ* these teeth are long, curved, and piercing, for tearing flesh and destroying life. In the *Canidæ* they are reduced in size, and are round and stout. In the Baboon they are still of large size, though reduced in the Monkeys and Apes, and are lowered to the level of the other

teeth in Man. In man the canines are reduced in form and size, but still retain suggestions of the features of these teeth in the Carnivora.

The *Tubercular* and grinding teeth. The very lowest form in which grinding organs appear are the cusped prominences on the triturating plates of the Crustacea and some insects, but these are not true teeth. They are, however, analogous to true grinding teeth, as they are employed for the same purpose. Very few of the Invertebrates possess triturating apparatus of any sort. In the Vertebrates, crushing teeth appear in some forms of fishes, which have well-developed pavement teeth of various forms for crushing the shells of mollusks and crustaceans. These are not true molars, however, as they do not triturate food nor insalivate it. Tuberculate teeth proper do not appear until the stage of the higher forms of reptiles, as some of the lizards have teeth, which are slightly tubercular, and these are the beginnings and forerunners of the molar series in the Mammalia. The lizards show the first tendency to the duplication of cusps, which are repeated over and over in various directions in the Mammalia. In the Mammalia the molar series is divided into two sections,—(a) the premolar (or succedaneous teeth), and (b) the true molars, which have no deciduous predecessors. The premolars are the small grinders which are found between the canines and true molars among mammals, and vary in number in different species. They

are the principal crushing members of the dental series, and are placed midway of the cutting and grinding teeth proper. In man the upper premolars (or bicuspids) are of simple form, being composed of two cones united together whose basis presents the two tubercles. The lower bicuspids vary from this form. In the higher Apes the premolars are of the same form as in man, but are coarser and larger. In the lower Quadrumana they are reduced to simple crushing teeth with the outer cusp enlarged and the inner reduced. In the *Carnivora* they are highly specialized on account of the tubercles being raised into large cutting blades. In the *Herbivora* they are similar to the true molars in form, and are developed for triturating purposes. In the *Insectivora* they are very variable in shape, but possess, like the true molars, long, sharp cusps for crushing insect coverings. In the *Rodentia* they are entirely absent from most of the species of this extensive order, as there is a large vacant space between the incisors and the grinding teeth. The true molars are found alone in the Mammalia, and are highly specialized teeth, being developed for the performance of the function of mastication. In the *Bruta* the teeth are all molars of a simple form, for crushing purposes. Some low forms have flat tooth-shaped plates of horn which answer the purpose of grinding teeth. In some of the ant-eaters the tongue and roof of the mouth are armed with horny plates for crushing. In the In-

sectivora the molars are highly developed, with many long, pointed cusps for crushing the hard coverings of insects. In man the molars are of simple tuberculate form of a lower grade of organization. His molar teeth are indeed of the type of the early Eocene mammals. In the Carnivora the molars are reduced in size and number, and the premolars are highly developed. In the more omnivorous species the number of molars is increased, and they have rounded tubercles for grinding a mixed diet. In the Herbivora the molars are highly developed for the mastication of an extreme diet, with pleatings and foldings of the dental tissues which insure a constantly rough face for the difficult reduction of resisting vegetable fiber. In the Quadrumana the molars are similar to these teeth in man, being simply tuberculate for a mixed diet.

The molar teeth of the Mammalia are classified as follows:

Haplodont. The crown undivided or simple (as in the single teeth of the *Cetacea, Carnivora, Rodentia*, etc.).

Ptychodont. The crown folded on the sides (as in the Rodentia molars).

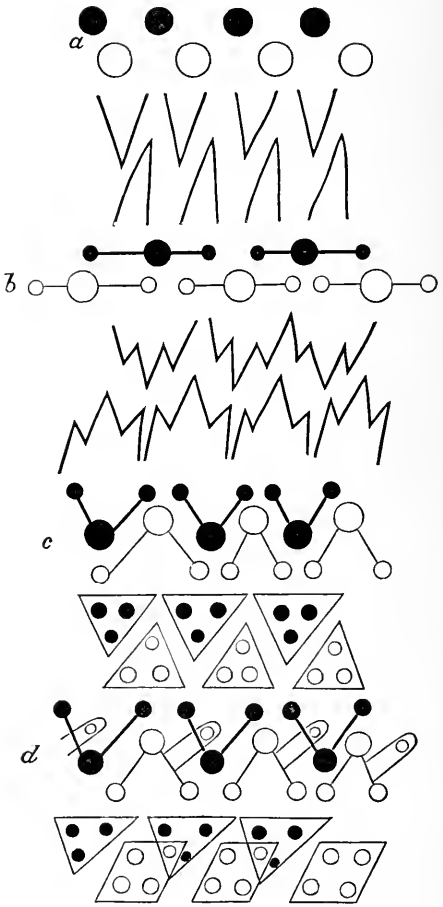
Bunodont. Crown supporting tubercles (as in man, Carnivora, Mastodon, etc.).

Lophodont. Summit of crown with transverse or longitudinal folds (as in Herbivora).

The molar teeth present great variety among

mammals, but all are derived by modification and duplication of the primitive, elementary cones and tubercles. The analysis of the genetic elements of the structure of the molar teeth shows them to be constructed of definite parts, which have been named in reference to the history of their evolution from the primary elementary cones. The primitive form of tooth (as exemplified in the living reptiles) is the simple cone and cusp, which represents this primordial element throughout the various phyla of mammals. This is called the *protocone*,—the first cone. In the premolars the protocone is the buccal cusp, to which, as the second stage in the development of these teeth, is added the second or lingual cusp, which is called the *deutcrocone*. Thus in man the buccal cusp is the protocone. From this type, which is found in the early Puerco formations, the premolar types of the higher mammals were developed by the addition of other cusps. The next stage was the addition of the third cusp posterior to the protocone,—called the *tritocone*. Sometimes a fourth cusp was added, called the *tetartocone*. In the lower premolars this relationship is repeated, with the difference of the termination,—*i.e.*, the *protoconid*, the *deutcroconid*, the *tritoconid*, and the *tetartoconid*, for the protocuspid, bicuspid, tricuspid, and quadricuspid forms of these teeth. In the evolution of the true molars there was first added to the primary protocone a small anterior cusp which is called the *paracone*,

FIG. 5.



PHYLETIC HISTORY OF THE MOLAR CUSPS. (After Osborn.)

a, The Reptilian stage. (Haplodont.)
b, Early Mammalian stage. (Triconodont.)
c, Triangular stage. (Tritubercular molar.)
d, Quadritubercular molar.

then a smaller posterior cusp called the *metacone.* This gives three cusps in a mesio-distal line, forming a three-coned crown called the *triconodont* form. This is the type of early forms of the mammalian molar teeth, and is still preserved in some of the Carnivora, seals, lemurs, and other living species. The next stage is the shifting of the cusps so as to alter their relative position to form a triangle. In the upper jaw the protocone moves to the lingual side (the mesio-lingual cusp), leaving the paracone (the mesio-buccal cusp) and the metacone (the disto-buccal cusp) on the buccal line, thus forming the *trigon* of the upper molar. This is the tritubercular molar crown of early geological times from which all other molar types were developed. This triangular molar is still preserved in the opossum, some insectivora, lemurs, and others. In the lower molar the primitive cone is called the *protoconid,* but it moves to the buccal side and becomes the mesio-buccal cusp. The *paraconid* (the mesio-lingual cusp) and the *metaconid* (the disto-lingual cusp) move to the lingual line. This forms the triangle of the lower molar,—the *trigonid.* (The paraconid has been aborted in man and some other mammals, so that the metaconid becomes the mesio-lingual cone or tubercle.) Thus the triangles of the upper and lower molars alternate,—the apex in the upper molar being directed lingually and in the lower buccally,—so that they pass each other with a shear-like motion. The next

stage is the addition to the trigonid of the lower molar, on its bucco-distal face, of a heel or *talonid* which supports one or two or three cusps,—the buccal of which is called the *hypoconid*, the distal the *hypoconulid*, and the disto-lingual the *entoconid*. The hypoconulid of the talonid below strikes into the valley of the trigon above like a pestle into a mortar, thus making a masticating appliance. Then there is added to the trigon of the upper molar on its disto-lingual face a talon which supports the fourth tubercle, the *hypocone*, thus making it a quadritubercular molar. These are the present forms of the molars in man, which are quite primitive in type. These forms are further complicated in the specialized teeth of other mammals by the addition of other cusps and tubercles, but the phylogenetic history of the molar cusps of even the higher forms can be traced with considerable accuracy through the various steps of their evolution from early geological times.

(8) The *succession* of the teeth in Vertebrates.

The Fishes and Reptiles have the teeth supplied in endless succession. When teeth are lost, others rise to take their places by various processes. In the Sharks and Rays, the teeth are supported by a fibrous membrane which carries them up over the edge of the jaw, bringing new ones into place as the old teeth are lost. Hinged teeth are replaced as lost by new ones which are constantly

developed at the base of the old teeth. Ankylosed teeth are replaced by the successive tooth being raised up beside or in the place of the old teeth, and new bone of attachment is reproduced to support them. Socket teeth are replaced by the advance of new teeth from within the body of the jaw when the old teeth are lost, as in man. In the Fishes and Reptiles many sets of teeth are developed during the life of the individual. In the higher forms the teeth arise *de novo* from the mucous membrane. The number is inconstant and indefinite.

In the Mammalia there are never more than two sets of teeth produced. Mammals are divided into two classes in reference to the possession of one or two sets: those having but one set are called *Monophyodont,* those giving rise to two sets are called *Diphyodont.* The monophyodont mammals produce but one set, which persists through life,—as some Armadillos, Sloths, Cetacea, the common Rat, and others. The first or deciduous set remains permanently, is more or less continually growing, and is never displaced by a second set. The diphyodont mammals have first a deciduous set which supplies the dental wants of the individual during the first years of existence. It is then shed and replaced by the permanent set, which remains during the lifetime of the individual. The teeth which succeed the deciduous teeth are called *succedaneous* teeth, but additional teeth are sometimes produced which have no deciduous prede-

cessors. Thus in man the ten anterior teeth are shed and replaced by permanent teeth, but there are also six additional teeth, the true molars, in each jaw which erupt without displacing any deciduous teeth.

The monophyodonts are usually *homodonts,—i.e.*, the teeth are all alike and of the same form in all parts of the jaw. The diphyodonts are *heterodonts,—i.e.*, the teeth are of various and different forms in various parts of the jaw,—as the incisors, canines, premolars, and molars of the Mammalia. So as a rule homodonts develop but one set of teeth, and heterodonts two sets, although there are noted exceptions to this rule.

In mammals the deciduous set arises *de novo* from the mucous membrane, and the permanent teeth are given off from the deciduous set. As a rule each tooth of the first set is displaced vertically by a similar tooth of the permanent set. There are examples, however, of milk teeth which have no successors, as some Rodent incisors, and of permanent teeth which have no deciduous predecessors, as the true molars. Some Rodents—as the rat—have but one set and are monophyodont. The elephant's molars succeed each other continuously from behind by lateral displacement. The Carnivora have a well-developed milk set. The Herbivora have also a milk set, but the true molars arise *de novo*. In the Quadrumana the two sets are similar to those of man.

QUESTIONS TO CHAPTER IV.

(1) Are true teeth the rule in Vertebrates? From what portion of the derm are they derived? Hence are called what? What is the main tissue of Vertebrate teeth? What are the other tissues and where found? Of what tissues are the teeth of Fishes and Reptiles composed? Of Mammals?

(2) Where are the teeth found in the lower Vertebrates? In Mammals?

(3) How many methods of attachment of the teeth are found in the Vertebrates? Name them. Describe the method by means of a Fibrous Membrane and give examples. By Elastic Hinge. By Ankylosis. By Implantation in Bony Socket.

(4) What is the typal form of teeth in Vertebrates? What varieties are found in the Fishes? In the Reptiles? How are the teeth modified in the Mammalia? How are incisors formed from the primitive cone? The canines? How are bicuspid teeth formed? Tritubercular? Quadritubercular? Are special teeth developed for special purposes? Give examples. How is the evolution of tooth form traced back through geological ages? How are the tubercles modified in Man? In the Carnivora? In the Herbivora?

(5) Do the number of the teeth vary in different Vertebrates? How does the number vary in Fishes? In Reptiles? In Mammals? Give examples. Is there great variety in the Mammalia?

(6) How are Vertebrate teeth classified? What are the various functions of the teeth in Fishes and Reptiles? Is there much difference in the teeth of different parts of the jaw in these classes? Are the teeth more differentiated in the Mammalia? Into what groups are they classified? What is an Incisor? A Canine? A Premolar? A Molar? How are they expressed in a mathematical scheme? What is the dental formula? Give the dental formula of man. What does it express? Give the formula of the deciduous teeth of man. How are single teeth to be expressed? Give the formula of the left upper central incisor. Of the right upper first molar. Of the left lower second molar.

(7) Describe the *incisors* of Mammals. Where are they found? In what bone above? Give examples. What is their function? How is the cutting function performed in lower forms? In higher forms? The Herbivora? In the Carnivora what teeth usurp the cutting function? What are the incisors like in the Quadrumana?

Describe the *Canines*. Where are they situated? Why called Canine? What is its principal function in mammals? What is its general form? How does it recall the type of the teeth of fishes and reptiles? Have the lower mammals conical, canine-like teeth all around? Name some mammals in which the canine is absent. Some in which it is excessively developed. How is it modified in the *Herbivora?* In what order does it attain its greatest development? In what family is it most highly specialized? Describe its form in the *Felidæ*. Is it reduced in the *Canidæ?* Tell of its form in Man.

What series of teeth succeed the canines? What grinding apparatus are found in Invertebrates? Are they analogous or homologous with the grinding teeth of the Vertebrates? Are crushing teeth found in the fishes? Are they true grinding teeth? When do true tuberculate teeth begin to appear? Of what teeth in the higher Vertebrates are they the forerunners? Into what two series are the tuberculate teeth of the mammalia divided? Which are premolars? Which true molars? Which have preceding deciduous teeth? What are the premolars called in man? Of how many cones are they composed in man? How are the premolars reduced in the Quadrumana? How are they specialized in the *Carnivora?* What function do they usurp? Are they similar to the true molars in the Herbivora? In what order are they absent? In what great class are true molars alone found? What is their function? What is their form in the *Bruta?* In the *Insectivora?* In man? Are the molars of very primitive type in man? Are they present in the *Carnivora?* How are the molars modified in different families of this order in relation to diet? How are they modified in the Herbivora in relation to diet? How are the molar series classified? What is the Haplodont form? The Ptychodont? The Bunodont?

The Lophodont? Is there great variety of the forms of molar teeth among mammals? How are the genetic elements of a molar crown to be analyzed? What relation have those parts to the evolution of the molar crown? What is the primitive form of tooth? What is the first cone called? Is the protocone the primordial element of all molar crowns? What is its position in the premolar crown? Where was the second cone added? What is it called? Where was the third cusp added, —when present? What is it called? What are the similar elements of the lower premolars called? What is the difference in the terminal syllable as between the upper and lower series? In the true molars, which is the protocone above? Which was the next cone added, and what is its name? The third cone or cusp? What are the three cones in a line called? In what living species is the triconodont form of molars yet found? In the next stage which cone shifted to the lingual side of the crown? Name and locate the cusps as then arranged. What is this triangle called? Is the triangular form of molars a very early form? In what species of mammals is it yet preserved? How are the cones named in the lower molars? What is the position of the protoconid? Which is the paraconid? The metaconid? What is the triangle of the lower molars called? How do the triangles of the upper and lower molars alternate? In which direction does the apex of each point? How is the trigonid extended in the lower molars? What is this extension called? What cones does it carry and what are they called? How does the talon strike the trigon above? How is the trigon above extended? Which cone does it carry and what is it called? Are these the forms of molars of man and are they like an early type? How are the other complicated molars developed from them? Can all the molar forms be traced to these early types?

(8) What Vertebrates have endless succession of teeth? Do the teeth succeed each other continuously in the fishes and reptiles? How do the teeth succeed each other in the fibrous membrane attachment? In Hinged teeth? In Ankylosis? In Socketed teeth? Are there many sets of teeth in Fishes and Reptiles? How does the first set originate? How does the next set arise? How many sets are found in mammals?

How are mammals divided in reference to having one or two sets of teeth? What are those having but one set called? Those having two sets? Do the teeth of Monophyodonts persist through life? Name some examples. What sets do the Diphyodonts have? When is the first set lost? What are the teeth which succeed deciduous teeth called? Name those teeth in man. What are Homodonts? Heterodonts? How do these compare with Monophyodonts and Diphyodonts? How do the deciduous teeth arise in mammals? How do the next succeeding teeth arise? How do they displace the deciduous teeth? Which teeth in man arise without any deciduous predecessors? Are the teeth of the rat deciduous? How do the molars of the elephant succeed each other? Is the succession of teeth in the Quadrumana similar to that of man?

CHAPTER V.

THE TEETH OF FISHES.

(1) THE first and lowest class of the Vertebrates is that of the *Fishes*. They are entirely aquatic in their habits, and breathe by means of gills. The body is bare, or covered with horny scales. The limbs are modified into organs for swimming. The nervous system is centralized in the spinal cord, but there is little enlargement of the cephalic portion. In the lowest forms, as the *Amphyoxus*, there is no enlargement at all. The osseous structures are soft and cartilaginous, and partake of the general low structure of the class. The vertebræ are cupped before and behind, except in the Pike and some other forms which show a step toward the reptilian character of being cupped in front and balled behind. The jaws are often movable and loose, and capable of protrusion and retraction.

(2) *The teeth of Fishes.* The true fishes have true teeth. There are many kinds of teeth among the many species of fishes, which are developed in every conceivable position upon the various bones and cartilages of the head. They are sometimes produced in countless numbers, as in the Salmon and Pike, or may be reduced to only one tooth, as in the Myxine, or there may be none at all. There is no general rule as to the number,

position, or form in this great class. They are very general in form and undifferentiated, and may vary extensively even among the individuals of the same species.

(3) *Forms and Function.* The teeth of fishes are derived from the simple cone, by various modifications. The conical teeth present great variety,—from long, fine, hair-like forms, to short, stout cylinders, and in others they may vary from cone to cylinder, from cylinder to plate. The teeth of fishes are designed for prehensile purposes mainly, as there are no masticating teeth proper in this class, though some species have pavement-like teeth, for crushing purposes. The conical teeth are often fine or hair-like; or so short as to be only felt with the fingers; or long and slender; or long and strong; or stout and short,—such teeth being attenuated cones in shape. The cone may merge into the cylinder, this into the compressed triangular form (as in the Shark), or stout with rounded summits (as in the Wolf-fish), or flattened plates (as in the Rays), or incisor-like form (as in Sargus). The arrangement is very general and indefinite also.

(4) *Structure.* The teeth of fishes are generally composed of vaso-dentin,—a soft dentin with a circulation,—the point of the tooth only being covered with enamel in some forms. This dentin is somewhat denser than the bone of the jaw, but is not so dense as the dentin of the higher Verte-

brates. In some forms it is not covered, and in others, as the Sharks, it is protected by a shiny enamel-like substance, but this is not true enamel. In other forms, as in Sargus, the dentin is yet harder, and is covered with a thick layer of dense substance developed by a distinct organ. Sometimes this enamel is covered by a layer of cementum. In others again there is a mere osseous substance which results from the calcification of the pulp.

(5) The *development and succession* of the teeth in fishes. In the great majority of fishes the germs of the teeth are developed directly from the mucous membrane of the mouth, throughout the whole period of succession. This is peculiar to the class. In all species the teeth are shed and constantly renewed throughout the whole life of the individual. Generally there is more than one successional tooth developing, so that several teeth are in process of formation destined to succeed one another in regular order. The mode of succession varies with the method of attachment, however, of which there are several in this great class,—*i.e.*, ankylosis, elastic hinge, and fibrous membrane. In ankylosed teeth, the most common form is for the new tooth to rise up under the old tooth and by absorption displace it; others displace the old tooth from the side by absorbing its supporting cone. Hinged teeth are developed in the folds of the mucous membrane, and as the old teeth are lost

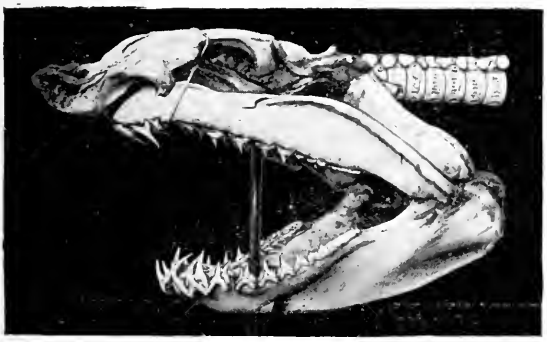
through use, new ones rise up to take their places. In the fishes having fibrous membrane attachment, the teeth are developed in the thecal fold on the inner side of the base of the jaw, and are perfected in growth as they are carried upward over the edge of the jaws by the membrane in which they are imbedded. Thus in the sharks the whole phalanx of the numerous teeth is ever marching slowly forward in rotary progress over the alveolar borders of the jaws, the teeth being successively cast off after having reached the outer margin and fulfilled for a longer or shorter period their appointed function, and are succeeded by others that rise up continually to take the places of those that are lost.

(6) *Descriptive.* In the cartilaginous fishes, the lowest forms, as the *Myxines, Lampreys,* and other parasitic types, we find some destitute of true calcified teeth, but instead possessed of a horny structure of a conical sharp-pointed and often slightly recurved form. Some, as the Hag-fish, have a lance-like tooth for piercing the victim to suck the blood. In others horny teeth may be developed upon the roof of the mouth or palate, or upon the tongue, or may be supported by peculiarly developed labial cartilages.

The *Elasmobranchii* (the Sharks, Rays, etc.) have the body covered—when covered at all—by tooth-like structures which are small and close set, and the layer is called *Shagreen.* When larger and more scattered they form dermal plates or tuber-

cles, and when they take the form of spines are called *dermal defenses*. These coverings constitute the "placoid exo-skeleton," which in minute structure precisely resembles teeth. The protruding surfaces are frequently ornamented with an elegant sculpturing of various patterns. There are no true jaws, but instead cartilaginous forms of the palato-

FIG. 6.



Teeth of Shark.

quadrate arch and of Meckel's cartilage. The teeth of sharks are always very numerous and arranged in concentric rows on the inside and summits of the mandible below, and the palato-quadrate arches above. They are imbedded in and borne upon the fibrous membrane which lines the inner surfaces of the arches, and by which they are carried forward over the edge of the jaws. The teeth lie flat against the membrane until brought to

the edge, where the turning brings them upright for use. Thus the first row stands upright on the margin of the jaw and does service until lost, then those of the next row rise up to take the place of those lost, and the succeeding rows follow in regular order,—the succession being endless. The teeth are developed from the bottom of a longitudinal fold of the lining membrane of the mouth at the lower edge of the jaws, called the *thecal fold*, from which they are continually carried up over the edge of the jaws. In all species the teeth are largest in the front or center of the jaws and diminish in size backward. The teeth of sharks are peculiarly adapted to the destructive habits of their possessors. The simplest form is that of a simple cone with a sharp point on a broad base, or it may be a triangular cone. In most of the sharks, however, the teeth are flattened into a triangular form, sometimes with serrated edges. These serrations are often deep and sharp, and the tooth makes a very effective implement for cutting and tearing. The teeth vary greatly as to size, and in former geological ages sharks existed whose teeth, found in the tertiary rocks, are of such large size that their possessors must have been enormous. These teeth measure five by six inches. The general form of the teeth of sharks is that of a sub-compressed triangle, but some forms have small accessory tubercles on each side of the central blade. Sometimes the blade is wide, short, and stout; again it is

long and slender, or oval or leaf-shaped; the flat faces are sometimes smooth, and again grooved or wrinkled.

The Sharks merge into the *Rays*, in forms which have both cutting and crushing teeth. The teeth of all Rays are in pavement-like arrangement of various shapes, and are formed for crushing purposes. They are quite in contact so as to form a more or less continuous sheath over the whole surface of the jaw. The shapes of the plate-like teeth are quite various, and sometimes present beautiful forms, in both recent and fossil species. Some are perfectly oval; some quadrangular (which fit closely together); some have raised ridges; in some the middle wave of the angle is raised into a sharp point; in some—as *Myliobatis*—the teeth are of horny or bony structure, and are closely joined together; in some forms the teeth are rounded eminences; in all varieties they are formed in a thecal fold imbedded in a fibrous membrane, are carried up over the edge of the jaw, and are replaced as lost (just as in the Sharks).

The Saw-fish is a Ray, and is remarkable for the unique elongated snout, which is covered on both edges with true teeth, set in bony sockets and growing from persistent pulps. This fish sometimes attains an enormous size, with a snout six feet long and twelve inches wide.

The *Teleostei*, or true bony fishes, possess teeth which are ankylosed to the various bones of the

head; some are hinged, and but rarely are they implanted in sockets. They consist usually of vasodentin with an irregular covering of enamel. The teeth are very numerous, and are scattered irregularly over most of the bones and cartilages of the mouth and head, even to the gills and occipital bones. In numbers they often run into thousands, as in the Pike, where the mouth is covered with sharply-pointed, conical teeth, sloping backward to hold struggling prey. Some of these teeth are large on the sides of the mouth, and may be hinged, and arranged in rows or in groups. The marginal teeth are usually ankylosed, but the palatal teeth are often hinged. The bands or groups are all directed backward to assist swallowing. The usual shape is that of a simple cone, but this is varied greatly, and may be fine and small, or large and long and recurved as in the Pike, Cod, and related forms. Or again they may be rounded and blunt as in the Wolf-fish; or so small as to be mere denticles on the jaws; in the *Gymnodonts* the teeth and jaws are fused into one mass like a beak; hinged teeth are found in the Hake, Pike, Cod, Angle-fish, etc., which assist in holding struggling prey; the Sargus has teeth of incisor-like form ankylosed to the jaw. The Eel has small, conical, enamel-tipped teeth; the Herring has minute, sharp-pointed teeth on jaws and tongue; the Salmon has sharp-pointed teeth distributed over the bones and cartilages of the head, etc. Many varie-

ties of teeth are found in this class, but all are related in arrangement and structure.

The Lung-fishes *(Dipnoi)* constitute a higher type which possess both lungs and gills which persist through life, in which they are closely related to the lowest form of reptiles, the Batrachians, and form the connecting link between fishes and reptiles. In the Lepidosiren there are two sharp-pointed recurved teeth, in the center of the jaw, and posterior teeth with molar-like cusps. Dentary plates are placed in the roof of the mouth, between which similar plates projecting from the mandible close for cutting purposes.

QUESTIONS TO CHAPTER V.

(1) Which is the lowest class of Vertebrates? In what element do they live? How do they breathe? How is the body covered? How are the limbs modified for locomotion? What is the form of the nervous system? What is the nature of the osseous organization? How are the vertebræ formed?

(2) Do the true fishes have true teeth? Where are they located? What is their peculiarity as to numbers? As to forms?

(3) What is the simplest form of teeth among fishes? How is the cone modified? Give examples. For what function are they mainly designed?

(4) Of what tissue are the teeth of fishes mainly composed? What kinds of dentin are found? Does enamel ever exist in the teeth of fishes?

(5) How are the teeth of fishes developed? Is the production of teeth continuous and unlimited? How is succession

effected in ankylosed teeth? In hinged teeth? In fibro membrane? Describe the process in the Sharks.

(6) What form of oral organs are found in the lowe kinds of fishes? In the Myxines? The Lamprey? The Ha fish? What are the Elasmobranchii? How does the extern covering of sharks resemble teeth? What names are given t it? How do the mouth parts differ from true bony jaws Are the teeth of the Sharks numerous? How are they a ranged? How are they supported? How does this fibro membrane bring them into place? How do they set on th membrane and how do they rise up on the edge of the jaws How are they replaced as lost? Where are they developed How are they carried upward? What are the various form of Sharks' teeth? How are they adapted to the habits of thei possessors? How do they differ as to size? What size wa attained in tertiary times?

What forms are closely related to the Sharks? What is th general form of the teeth of the Rays? Describe some of th special forms. For what purposes are they used? Do they originate and succeed each other like the teeth of Sharks? Describe the snout and teeth of the Saw-fish.

What are Teleostei? How do they differ from the cartilaginous fishes? Where are the teeth located in this division? What is their tissual organization? Their number? Their form? How are they attached? What is the difference between ankylosed and hinged teeth? How are they generally arranged? Give some details of arrangement in the Pike. What is the form in the Wolf-fish? The Eel? The Herring? Are the teeth closely related in this division?

What is the peculiarity of the *Dipnoi?* Do they approach the Amphibia? What sort of dental apparatus have some of these intermediate forms?

DENTAL ASSOCIATION

CHAPTER VI.

THE TEETH OF REPTILES.

(1) THE second class of Vertebrates is the *Reptilia*, which are more highly organized than the fishes and approach Mammals in some of the higher forms. They are cold-blooded, breathe by means of gills in the lowest types and by lungs in the higher, and are covered with a tough, leathery skin or by horny scales.

The class is conveniently subdivided into two main divisions,—(1st) the *Batrachians* (or Amphibia), and (2d) the true *Reptiles*. The Batrachians are the lowest form of Reptiles, and approach the fishes in the degraded structure they exhibit. They are the connecting link between the fishes below and the true reptiles above them. They breathe by means of gills, and are aquatic during the first or larval stage of existence, and later change to air-breathers—as the common Frogs, Toads, and Newts—on attaining maturity, and live both on land and in water. Other forms—as the Proteus—retain the gills through life. The true Reptiles are lung-breathers, and live mostly upon land. They have four limbs, except one large order,—the *Ophidia*, or Snakes, which are without limbs.

(2) The *teeth* in the class *Reptilia* are not so

numerous nor so widely distributed as in the class Fishes. They are confined to the borders of the jaws, except in some of the Batrachians which resemble the Fishes in having the dentary bone and vomer carrying teeth also. Reptiles usually have an endless succession of teeth, which are replaced as shed as in the Fishes, and which are composed of hard dentin with a thin layer of enamel in some species. One entire order, *Chelonia* (Turtles), are without teeth, but have horny sheaths for the jaws instead, like the beaks of birds. The teeth of Reptiles, like those of Fishes, are employed for prehension and for holding struggling prey, for mastication is not performed to any extent in this class.

(3) In the *Batrachians* the teeth, when present, are disposed in rows upon the borders of the jaws and the two vomers above, between which the mandibular row closes. This is shown in the common frog. Some types, as the *Siren*, have the jaws ensheathed with horny beaks. In the larval stage the Frog (the "tadpole") also has the jaws covered by horny sheaths, which are lost at the time of the metamorphosis when the true teeth appear. The teeth are ankylosed to the bone like the teeth of fishes, which they much resemble.

In the common *Frog* the teeth appear at the time of the metamorphosis, when the tail is lost and the legs appear, and the gills are aborted to be replaced by lungs. The teeth appear on the maxillary and premaxillary bones, but not on the mandible, as

the frog has no perceptible teeth on the lower jaw. The teeth form a single row around the margin of the upper jaw,—their points projecting but little above the membrane,—against which the lower jaw closes, there being no lips. The teeth are ankylosed to the bones, each one being perched upon a little pedestal of bone. The successional teeth move up beneath the old ones and push them off. The teeth are mere delicate cones of hard dentin, with a thin layer of enamel.

The *Toads* are practically toothless, and have no compensating structures.

The *Newts* and *Salamanders* sometimes have conical teeth that are bifurcated at the points and are tipped with enamel. Some species have great numbers of teeth, like the Teleostei fishes.

The *Sirens* have horny sheaths on the jaws (like the larval form of all the *Batrachians*), and teeth also on the vomers and on the sphenoidal piece of the mandible.

The Alleghany *Menpomona* is a typical Salamander. There is a groove upon the edge of each jaw, in which the teeth rest by an enlarged base on the bottom and the points just rise above the margins of the groove. The teeth number sixty to eighty in each jaw; are about equal in size, sharp-pointed and recurved. They are attached by ankylosis to the outer walls of the groove,—a method of attachment called "pleurodont," because of its resemblance to the attachment of the ribs.

The *Axolotl*—a peculiar Mexican lizard with permanent gills—has rasp-like teeth, of a fish-like character. The *Proteus* also has permanent gills. It has sharp, fine teeth in front and a horny palate behind. The teeth of some extinct Batrachians whose remains have been preserved in the rocks present some remarkable features. The *Labyrinthodont* form was so named on account of the extraordinary folding of the dental tissues, which were longitudinally crimped so that in a section of the tooth it looks like a roll of pleated and crushed cloth. The pulp-cavity was subdivided into a number of radiating branches which reached out into the folds.

(4) The teeth of the true *Reptiles*, with few exceptions, present simple conical forms with more or less sharp points, which vary in length and are circular or oval on section. The teeth are longest and the points sharpest in the snakes; or short and blunt in the crocodiles; or tubercular, as in some lizards, etc.

Teeth do not exist in all reptiles, as one whole order, the Chelonia, and some snakes are edentulous. They may be present on the jaws only,—as in the crocodiles, lizards, etc.,—or upon the palatine and pterygoid bones, or the intermaxillaries. Some toothless snakes have the inferior spinous processes of certain cervical vertebræ prolonged to project within the walls of the œsophagus for the crushing of the shells of eggs on which such species

feed. The teeth are usually implanted in sockets in the true Reptiles, though the lizards and snakes often have them ankylosed to the jaw. The root is single, and never branches into fangs as in mammals. They are continuous in succession like the teeth of Fishes and Batrachians, and this proceeds through life, teeth being shed and replaced without cessation. The teeth are composed of hard dentin with a thin layer of enamel on the apex.

(5) The *Lacertilia* comprises the Lizards, Chameleons, Iguanas, etc. The *Iguanodon* and other great extinct lizards are also related to this order. They are distinguished from the other reptiles mainly by the presence of clavicles. The skull is intermediate between crocodiles and turtles. The teeth are attached by ankylosis, like the Batrachians, and in this and other features they approach that low type. The teeth are of simple conical form, of various sizes and shapes; sometimes the maxillary teeth have serrated edges and the beginning of tuberculated crowns. The apices only were sometimes covered by enamel. The pulp-cavity sometimes has numerous divisions. The succession of teeth is constant,—new teeth being developed by the side of the old ones and displacing them by absorption, as is the usual form of succession in ankylosed teeth. The Lacertilia all possess teeth, which may be confined to the maxillary, premaxillary bones and dentary pieces of the mandible, or may in addition be developed on the

palatine and pterygoid bones. The form is usually conical, but there is a suggestion of approach to mammalian types. Thus the Frilled Lizard has canine and incisor-like teeth, and other species have cuspidate crowns, or with cingules on the sides of the crowns. The *Stillio* (or little flying dragon) has long canine-like teeth, with tricusped crowns behind. The Chameleon also has cusped molars for crushing insects which it catches with its long tongue. The Monitor has sixteen teeth above and fourteen below, which are sharp-pointed and conical. The "Horned Toad" has conical teeth on the palatine and pterygoid bones as well as on the maxillaries. The horned *Iguana* has teeth in the posterior part of the jaw which have expanded crowns, with a blade of spear-like form with serrated edges. The "Gila Monster" *(Heloderma)* is a large lizard of Mexico and Arizona, which has teeth of thin, flattened spear-shape with apparent grooves, which increase in size from front to back. The bite is said to be poisonous, but its toxic effect may be due to the saliva only. A New Zealand lizard (*Hatteria*) has the intermaxillary bones armed with two teeth so large as to be as wide as the jaw, and which resemble the scalpriform teeth of the Rodents. When worn down to the jaw, the bone then comes into use and is worn away with the teeth. The African "Frilled" Lizard (*Dicryodon*) has sharp margins to the jaws, and also large canine-like tusks projecting down-

ward from the upper jaw which grow from persistent pulps,—a very rare thing in the Reptiles.

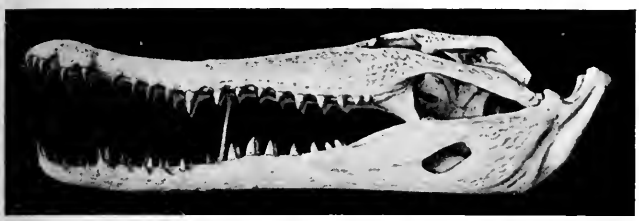
The extinct lizards were remarkable animals. The *Plesiosaurus* was a form of lizard with long neck and small head, and the limbs modified into paddles for swimming. They varied much in size, some being very small. The teeth were sharp-pointed, recurved, and the external surface of the crown striated. Each tooth was lodged in a distinct socket. Some were of triangular shape on section, with two cusps, and sometimes rounded off. The *Ichthyosaurus* is an extinct lizard of gigantic size, with paddle-like limbs, and was remarkable for the extraordinary enlargement of the eyeballs, which had ossified sclerotics. It had long, narrow, flattened teeth, formed of folded plates of enamel. The *Iguanodon* had remarkable teeth. Some were flat and spread out like a fan with serrated edges,—the base constricted and composed of folded laminæ of dentin and cementum, similar to the teeth of the Labyrinthodont. The *Pteryodactyls* were flying lizards with wings like a bat, which in large species reached the width of twenty-five feet. Most species were quite small, however. The jaws were armed with long, slender teeth for their whole length. The *Mososaurs* were marine lizards of great size, with large recurved teeth of simple form attached by rounded bases to the bones of the mouth.

The *Crocodilia* are related to the lizards, but

much more advanced in structure in many respects. This order comprises the Crocodiles, Alligators, Caimans, Gavials, etc. They are all covered with a dense exo-skeleton of hard, calcified scutes forming a strong coat of mail, and which are variously sculptured. The teeth are numerous, being confined to the margins of the maxillary, premaxillary, and dentary bones and mandible. The upper and lower alternate and interlock when the mouth is closed, as with most reptiles. The teeth are rounded, conical, more or less compressed or oval in section, and rather blunt. They are much reduced from the long, cone shape of the fishes and vary much in shape; some are long, curved, and acute; others are short and obtuse, and others have a flat, sharp edge which may be serrated. The forms are very erratic, even in the same species. They are composed of fine, hard dentin, covered with cementum and with enamel in some species, usually a thin layer confined to the point. The teeth are implanted in sockets which are formed by septi crossing the dental groove, which is open and continuous in most of the lizards. New successional teeth are being constantly developed beneath or at the sides of the old ones. As a new tooth erupts it presses against the base of the old one, causing its absorption, and, pushing it upward, carries it like a cap on its apex until it is lost. The successional teeth follow each other and become "nested" one within the other. In the Crocodiles

proper the teeth are set on the margin of the jaw in distinct sockets, and are long, conical, somewhat pointed, and compressed to form sharp edges. The teeth vary much in size and form in different individuals, and also in the same individual at different

FIG. 7.



Crocodilus niloticus.

FIG. 8.

Teeth of Alligator.

times. They are small in front and increase in size to the side, and then diminish toward the back. The Crocodile differs from the Alligator partly by the presence of the notch on the side of the muzzle into which the so-called lower "canine" passes, in-

stead of the fossæ of the Alligators. Both Crocodiles and Alligators are remarkable for the breadth and flatness of the muzzle and for the alternate increase and decrease of the teeth in the series from front to back. The Alligator of the Mississippi has eighteen to twenty-two teeth on each side of the upper jaw. The teeth in front in the premaxillary bones are the smallest. These increase in size to the fourth, which is nearly twice as large as the others; the first of the maxillary teeth are the smallest; the third is the largest,—the so-called "canine,"—the ninth tooth from the median line. The eighth and tenth are sometimes as large or larger than the ninth. The teeth then decrease in size, then increase again to the seventeenth, then decrease to the end of the series. The posterior teeth are sub-compressed, with a more or less rounded eminence. The teeth of the lower jaw are likewise of unequal proportion, the smallest and largest alternating with the smallest and largest above. The largest caniniform tooth below is received into a deep fossa just inside of the fifth or sixth tooth above. In old individuals it sometimes happens that the lower teeth become of such a length as to penetrate through the thin upper jaw entirely and appear outside when the mouth is closed. This also occurs in the Caimans of South America, which are like the Alligators in regard to their dentition. The Gavials of India have a remarkable snout, which is elongated, narrowed from

the cranium, and again enlarged to a spoon-shape at the end. Owing to the extra length of the jaw, it has more teeth than the crocodiles, and they are of more uniform size. The "canine" tooth fits into a notch on the side of the muzzle like that of the crocodiles. The extinct crocodiles were characterized by larger and more numerous teeth, which sometimes had longitudinal ridges upon the crowns.

The *Ophidia* comprises the serpents of all kinds, which are of well-known form, and have neither limbs, scapula, thoracic nor pelvic arches,—except in the *Boas*, which have a rudimentary pelvis and hind limbs. The skin is covered with glittering scales, which are smooth in the non-poisonous species and keeled in the poisonous varieties. The bones of the skull are loosely joined by elastic ligaments. This provision enables the snakes to open the mouth to a prodigious extent and to protrude and retract the jaws, so as to inclose and swallow prey as large or even larger than the body of the snake itself. A toad, twice or three times the diameter of a snake, can be swallowed by working the jaws up over it gradually, advancing first one jaw and then the other, the recurved teeth holding the bite as it progresses and thus forcing the object slowly downward into the œsophagus. The teeth of the serpents are very uniform,—of simple conical shape, recurved, and very sharp,—and are used for prehension only. The cone-shape

tooth attains its most perfect development, is largest and longest in this order, as illustrated in the poison fangs of serpents. The number of teeth varies extensively, and they are supported by the maxillaries, dentary, pterygoid bones and the mandible. The poisonous species are armed with the poison fang, which is long and sharp and is formed into a tube to inject the poison hypodermically.

FIG. 9.

Teeth of Rattlesnake (*Crotalus adamanteus*).

Some poison fangs are erectile, as the Rattlesnake; others are upright and rigid, as the Cobra. They are connected by the basal opening of the tube with the poison sac, which occupies the temporal fossa, the contents of which are pressed out by the action of the external pterygoid and temporal muscles when the mouth is widely distended. The tubular tooth through which the poison flows and is injected into the flesh is formed as if a conical tooth had been flattened into a thin sheet and then rolled

so that the edges were brought together to form a tube, so that all the tissues are flat, even the pulp, —the inside of the tube being like the outside of the tooth, although the interior is not lined with enamel in all species. The tube opens a short distance from the point like a hypodermic needle, so that the point must be well implanted before injection can take place. These teeth are much recurved when erectile, and lie flat against the roof of the mouth in a fold of mucous tissue when not in use; they are raised by the moving backward of the lower jaw and quadrate bone, which pushes the upper maxillary forward and erects the fang when the strike is made. They are reproduced when lost by a vascular pulp situated posteriorly. In the Rattlesnake, ten reserve teeth have been found. All the viperine poisonous snakes—the Rattlesnakes, Puff-Adders, Vipers, etc.—have the poison apparatus highly specialized. The maxillary bone carries no teeth back of the poison fang. In the species having these teeth permanently erect, as the Cobra, they are also reproduced indefinitely as lost.

The non-poisonous snakes have two rows of teeth in the upper series and one in the lower, which are strongly recurved and irregular in size. They are ankylosed to the jaw, and reappear as lost. They are composed of hard dentin with a thin external layer of cementum and enamel. In the Boa Constrictors, the teeth are slender, conical,

and slightly recurved. This enables them to creep up with the alternating motions of the jaws over disproportionately large objects, and force them backward into the œsophagus. The teeth of the Pythons are all simple, recurved cones. Some are grooved and perhaps constricted at the neck. In the Colubers the teeth are similar,—the largest being in front and diminishing in size backward.

The *Chelonia* comprise the turtles, land and water tortoises, etc. In these curious reptiles the endo- and exo-skeletons are combined to form the very singular box-like structure, the *carapace*, which incloses and protects the animal's organs. The skull is solidly combined in one piece. The oral armature is remarkable in that there are no teeth whatever, but the maxillaries and mandible are inclosed in hard, bony cases which form beaks like the strong bills of birds. These beaks are variously formed, being in a general way sharp and thin-edged in the carnivorous species and adapted to cutting, and blunt and flat in the herbivorous types and adapted to crushing vegetable substances.

(6) The fourth class of Vertebrates, the Birds *(Aves)*, are warm-blooded and clothed with feathers, which by special modification and general structure enable them to fly through the air. Birds are closely related to the reptiles in many respects, and are probably descended from a common ancestral form with them.

This class is unique in that none of its living members are provided with teeth, but instead of which the elongated maxillæ and mandible are covered with horny structures called bills or beaks, which take the place of teeth and perform the dental offices. The beak is the prehensile and cutting organ, and is variously modified to adapt it to the different kinds of food employed. Mastication, when necessary, is performed by the gizzard, a strong, muscular stomach. The beak is short and strong in the grain-feeders; long and slender in the insect-eaters; short and gaping in the Swallows and Night-Jars; hooked, sharp, and strong in the Eagles, Vultures, Hawks, and other carnivorous species for tearing flesh; long and stout with a chisel-like point in the wood-cutting Woodpeckers; short, wide, and curved in the Parrots and others which crush nuts, etc.; long, tapering, and delicate in the Humming-Birds for penetrating the corolla of flowers to suck honey; ponderous and ungainly in the Horn-bills and Toucans for cutting and crushing; long, strong, notched, or variously modified for catching fish in the Storks, Herons, Pelicans, Penguins, Kingfishers, etc.; flat, elongated, with soft sensitive edges, for separating food from sand and mud in the Swans, Geese, Ducks, Spoonbills, etc. In all birds, as in other animals, there is a direct adaptation of the tools to material, —of oral apparatus to the kind of food employed by each species.

While no living species of birds possess teeth dental pulps are sometimes found in the jaws o bird embryos, as the Parroquet, showing that the retain a reminiscence of a former toothed stage i the history of their descent. That there was such a stage is now demonstrated, for fossil birds with teeth have been found. The Cretaceous formations of the West have yielded one hundred and fifty species. One group is called *Odontonithes* some of which are quite small and had teeth in distinct sockets. Another group were very large swimming birds, and had teeth set in grooves. In *Ichthyornis*, the teeth are about twenty-two in each jaw, all sharp and recurved, with crowns flattened and covered with enamel. In *Hesperornis* the teeth were also socketed. The group presents a regular gradation from groove to socket in the methods of attachment of the teeth. The forms of these teeth are of distinctly reptilian type, and indicate the link between birds and reptiles.

QUESTIONS TO CHAPTER VI.

(1) What is the second class of Vertebrates? How do they differ from the Fishes? Into what two main divisions is the class divided? In what respect are the Batrachians nearer the fishes than the true reptiles? How do they breathe in the larval stage? In the adult stage? How do the true reptiles breathe?

(2) Are the teeth as numerous as in the Fishes? To what bones are they mostly confined in the true Reptiles? Do they

ve endless succession of teeth as the Fishes? Of what are ey composed in the Reptiles?

(3) In the Batrachians, what bones support teeth? How e they attached in this division? How are the jaws armed the larval form of some Batrachians? When do teeth apar in the common Frog? What other changes take place the time of the metamorphosis? In which jaw does the og have teeth? Which jaw is edentulous? How do they ose? What are the teeth like? How is succession effected? re the Toads edentulous? What are the teeth of Newts id Salamanders like? How are the jaws of the Sirens proected? Describe the teeth of the Alleghany *Menopoma*, as a pical Salamander. Also the teeth of the *Axolotl;* the Prous. Also the great extinct batrachian, the *Labyrinthodont.* ow are the dental tissues arranged in this remarkable form?

(4) What is the form of the teeth of the true Reptiles? In hat form are the teeth sharpest? In which bluntest? In hich forms are tubercles found? What Reptiles are without eth? Upon what bones are the teeth located in Reptiles? Vhat forms have the spinous processes elongated to project to the œsophagus? What is the mode of attachment in ie Crocodiles, Lizards, and Snakes? Is the succession conuous? Of what are the teeth composed?

(5) What Reptiles does the order *Lacertilia* comprise? Vhat is a distinguishing characteristic as compared with other eptiles? How are the teeth attached in the lizards? What is ie general form? Do tubercles begin in this order? Of hat tissues are the teeth composed? How is succession ffected? What bones are they located on? Describe the eth in some forms of lizards (giving names). What are me of the extinct forms of lizards and what form of teeth d they have (giving names)?

What Reptiles does the order *Crocodilia* comprise? What is ieir general form? How are they protected? To what nes are the teeth confined? What is the form of the teeth? low do the forms vary in the order? Of what are they comosed? What mode of attachment prevails in this order? low is succession effected? Is it continuous through life? low do the teeth of the Crocodiles vary in size? How does

the Crocodile differ from the Alligator? How many teeth does the Alligator of the Mississippi usually have? How do these vary and change in size from front to back?

What Reptiles does the order *Ophidia* include? What is their general form? Are limbs ever present? How is the skin covered? How are the bones of the jaw and skull articulated to enable them to swallow disproportionately large prey? How is this deglutition effected? What is the special form of the teeth of the serpents? Does the number of teeth vary in this order? What bones support teeth? What varieties of attachment are found in the order? Describe the attachment of the poison tooth and of the prehensile teeth. In what teeth is the cone shape the highest developed? Describe the poison tooth. How is the tube for injecting poison formed? How are the tissues arranged? How is the poison injected? How is the fang attached in the viperine poisonous snakes? In the Cobra? How are they reproduced? What kind of teeth do the non-poisonous species have? How are they arranged? How attached? How is deglutition effected in the Boa Constrictors, Python, etc.? How do they vary in size?

What order of Reptiles are entirely without teeth? With what is the jaw covered in the turtles? How do the jaw coverings of the vegetable-eating and carnivorous species differ?

(6) What great class of Vertebrates are entirely without teeth? What special modifications distinguish the birds from all other Vertebrates? What jaw structures do they have as substitutes for teeth? What are the bills or beaks composed of? How do the beaks of birds differ so as to adapt them to various kinds of food, as the teeth are modified? How is mastication performed in this class? Give some examples of modification of the bills of birds to the diet employed.

Have extinct species of birds been found which possess teeth? Does this imply that the ancestors of the birds were once possessed of teeth? How is this demonstrated in the case of the Parroquet? In geological forms? Where have fossil birds been found? What sort of teeth had the *Odontonithes?* The *Ichthyornis?* Are these teeth of distinctly reptilian type? Do they show the relationship of birds with reptiles?

CHAPTER VII.

THE TEETH OF MAMMALS.

(1) THE *Mammalia* are the highest of the Vertebrates and the most elevated in structure of the entire animal kingdom. They are more highly organized and the organs are more specialized than either Fishes or Reptiles, being the highest result of the evolution of life that has been progressing on the earth since its creation. They live upon the land and in the air and water, and the variety of organization is very great to adapt them to the varied life of these elements.

They are so named from possessing mammary glands, by which they suckle the young during the first stages of existence. Mammals are *viviparous*, —*i.e.*, the young are born alive,—while all the classes below them are generally *oviparous*,—*i.e.*, the young are born from eggs. They are first nourished by the milk of the mammary glands. In size, mammals vary from that of the tiny harvest mouse of Europe (weighing scarcely an ounce) to that of the great whales or the extinct mammoth. The body is bare or is covered with a variety of hairy growths, or horny plates, as the armadillo. There are usually four limbs present, hence they are called quadrupeds,—four-footed animals.

The heart is four-chambered and the blood warm. Respiration is performed by cellular lungs. The osseous system is more rigid and stronger than that of the lower Vertebrates, owing to the coalescence of bones which remain distinct in the latter, and to the greater solidity due to a larger quantity of lime-salts. The bones of the skull and jaws are more solidly united, and the number of bones is reduced. The mandible arises from distinct centers of ossification (which represent distinct bones in the fishes and reptiles), but it usually consists of a single bone in the adult mammal. In most of the lower mammals the superior maxillaries are more elongated than in man, and the intermaxillary bones remain distinct through life. In man they are fused with the maxillaries.

(2) The *teeth of Mammals* present great variety, as the food employed is varied, and highly specialized teeth are developed to accommodate the food habits. Some low forms are destitute of teeth, but nearly all mammals are possessed of true teeth. The offices of the teeth are also extended in this class, for while in the fishes and reptiles the teeth are mainly employed for the purpose of prehension only, in the mammals special forms of teeth are developed for the performance of special functions. Thus there are teeth for prehension, for cutting, for crushing, and for mastication. The grinding teeth are highly elaborated, for mastication has become an important factor in the more highly com-

plicated digestive system. The teeth are important to the alimentary system, for by them food is secured and reduced to prepare it for digestion, so that their office is indispensable.

The teeth vary in number among mammals,—from the single tooth of the Narwhal to the hundreds of teeth of the Dolphins. The primitive form of teeth, the simple cone, is presented by the fishes and reptiles, with but little variation, but in the Mammalia there is a wide departure from the primitive typal cone. This is modified and duplicated to an extensive degree to furnish the many forms found among mammals. The primitive cone is modified to adapt the teeth to the performance of their various functions,—*i.e.*, prehension, cutting, and mastication.

The attachment of the teeth in mammals is by but one method,—that of implantation in a bony socket, or *Gomphosis*. The roots are single or divided into two or more fangs. Sometimes the roots are completed and the apex closed except the small foramen for the vessels supplying the pulp with nutrition, or again the pulp may be permanent and the tooth be of continuous growth.

Three tissues enter into the composition of the teeth of mammals. (1) The *dentin*, a dense osseous tissue like ivory, with radiating canaliculi, which is formed in the submucous tissue; (2) The *enamel*, which covers the crown, which is developed from the epithelium of the mouth and con-

sists of calcified epithelial cells; and (3) the *cementum*, which encases the root, which is like the true bone in structure and organization. These three tissues are found in most mammals in varying degrees of completeness, except that enamel is absent from the teeth of some low forms, as the ant-eaters, sloths, and others.

The relationship of the teeth of Mammals with those of the Fishes and Reptiles below them is well marked, and they present many resemblances as well as some differences. The earliest as well as some living lower mammals present reptilian characteristics. Thus the teeth of the Dolphin and other cetaceans are conical, curved, and more or less devoid of enamel, like reptilian teeth. The highly specialized teeth of the higher mammals differ from those of the lower mammals as they do from reptiles. There are some important differences between the teeth of reptiles and mammals. Thus reptiles never have more than one root, while mammals may have two or more distinct fangs. Implantation is the exclusive mode of attachment among mammals, but this is also imitated in the crocodiles and some other reptiles. Heterodontism (having teeth of different forms in the same jaw) is a mammalian characteristic, but the lizards also have this feature to a limited extent, in which the tubercular form begins to manifest itself. The number of the teeth is reduced in mammals, though some, as the dolphin, have a great number. Suc-

cession is reduced, as there are never more than two sets in the mammals and there may be many in the reptiles. The elaboration of the crowns by the duplication of the primitive cone is an exclusively mammalian character, for the repetition must be shown in the root also. The primitive cone is of course reptilian, and from this all teeth, even the most highly specialized, were developed. The series is continuous throughout the vertebrate series, and the homologies are apparent in all stages.

FIG. 10.

Duck-billed Platypus (*Ornithorynchus anatinus*).

(3) *Descriptive.* The lowest order of the Mammalia is that of the *Monotremata*, which includes but two species, the *Ornithorynchus* (or Duck-bill mole) and the *Echidna* (an ant-eater). These are, dentally, the lowest forms of living mammals, and present the anomaly—like the lowest species of fishes and reptiles—of possessing horny structures which take the place of teeth. The Ornithorynchus is a mammal living in Australia with a bill like a duck, and like the duck's bill transversely ridged to strain food from the water. Each jaw is pro-

vided with four horny teeth, of which the two front ones have long ridges and the back ones are tubercular and calcareous, somewhat like true grinding teeth. Their structure is a fibrous, horny substance, like hoofs or nails, with only three per cent. of earthy matter. The other member of the order, the Echidna, has an edentulous bill, but with the tongue and roof of the mouth covered with horny spines to crush the ants caught by its viscous tongue.

FIG. 11.

Little Armadillo (*Euphractus minutus*).

The next highest order of mammals is that of the *Bruta*, which comprises the Sloths, Armadillos, Ant-eaters, etc., which are of very low organization. They were first called *Edentata*,—without teeth,—and later were described as being without incisor teeth, as median incisors are absent in all the members of the order. The teeth are also destitute of enamel, the dentin alone being exposed to wear. The teeth are of continuous growth, and are usually monophyodont. Many of this order feed only on insects, the long whip-like

tongue being covered with a viscous mucus to which the insects—principally ants—adhere. For this simple diet the teeth are reduced and degenerate in form and structure. The teeth are usually confined to the maxillary bones only, the premaxillaries being destitute. In the Cape Anteater, the teeth are all molar-like in form, increasing in size from front to back. They are oval on section, and two facets are produced by wear as the teeth in the upper and lower series alternate on striking. The formula is m. $\frac{7-7}{6-6}=26$. The Armadillos are peculiar for the shell-like covering in which the animals roll up, when attacked, for protection. They may have large numbers of teeth,—ninety-six to one hundred being found in some species. These are of simple, molar-like form, increasing in size from front to back, and are compressed laterally, with oblique surfaces. Sometimes there are enamel germs in the embryo, but these are absorbed as the tooth develops, so that the tooth has no enamel. The teeth alternate, and are worn in distinct facets. Some species, perhaps all Armadillos, have a successive set. The Sloths are hairy mammals of arboreal habits, which suspend themselves beneath limbs by means of the powerful claws, which are formed for hanging down and moving about in trees. They have few teeth, the formula being mostly m. $\frac{5-5}{4-4}=18$, implanted in the maxillary bones above and the mandible below.

They are of molar-like form, and increase in size from front to back. The tooth is composed of a central axis of vascular dentin with an outside investment of harder dentin, and grows continuously. The grinding surface is usually cup-shaped, the hard rim presenting two or more points. These curious mammals are found in South America, and are probably descended from the great extinct Megatheroids of the Pampean formations. The gigantic *Megatherium* (an immense Sloth of earlier geological times) had the same formula and the same kind of teeth as the present sloths, but the wear of the crowns produced two transverse crests.

The orders of *Cetacea* and *Sirenia* include the aquatic mammalia which have been transformed for life in the water. The *Cetacea*—the Whales—have simple teeth, of blunt canine shape, or have mere horny substitutes for teeth. The Baleen Whales have a horny substance in the form of plates hanging down, which fringe out at the end to form bristles. This is the baleen or "whalebone" of commerce. It consists of bundles of plates triangular in outline, arranged in rows on each side of the upper jaw. A row of smaller plates is internal to the outer row. Each plate is developed from a vascular pulp, and is of continuous growth. There are sometimes two hundred of these plates, and the width of the matrix is often two feet. The whalebone is fringed and frayed out at the ends, and this fringe is employed by the animal to

strain the small sea animals, which are found in the Arctic regions, from the water. The whale gulps a quantity of water containing the animals, and then closing the mouth ejects the water through the fringe, thus straining the animals out. Tooth-pulps are found in the embryonic stage, but these are absorbed and disappear as the baleen is formed. The Sperm-whales (*Cachalot*) have often fifty-four teeth on the lower jaw, but the number varies, the upper jaw being edentulous. These are short and stout, of recurved form, and are worn obtuse by use. In the Narwhal the teeth are all suppressed except the tusk incisor in the left intermaxillary bone. This grows until it sometimes attains the length of eight or nine feet, and a basal diameter of four inches. The exterior of the tusk is marked by spiral ridges, which wind around the tooth from the left. The right side has a small suppressed tusk, but it is like the concealed tusk of the female, for the male only has the long tusk. The Porpoise has eighty to ninety teeth of flattened, cusped form, which alternate like the teeth of reptiles, with the largest teeth on the side of the jaws. The Dolphin has the most numerous teeth of any mammal, often reaching one hundred and ninety to two hundred, as in the common dolphin. These teeth are sharp, slender, conical, and recurved, diminishing in size each way from a large tooth on the side of each jaw. The teeth of the Cetacea exhibit an interesting degradation of form, as tooth

germs are found in fetal life in the edentulous species. The gradual closing and obliteration of the dental groove in fossil forms has even been traced. The *Sirenia* comprise the herbivorous Cetaceans, of which there are but two genera now living,—the Dugongs and Manatees. In the Dugong the end of the upper jaw is bent downward, forming an angle with the body of the jaw, in the

FIG. 12.

Teeth of Dugong.

end of which two tusk-like incisors are implanted. These are thickly coated with enamel on one side, but absent on the other, so that wear produces a sharp edge. Dense, horny plates are placed farther back on the jaw, under which rudimentary teeth are found, and beyond these are molars of dentin and cementum. The Manatee has thirty-six teeth, with square crowns with transverse ridges. The upper molars have three roots and the lower two. There is a deciduous premaxillary

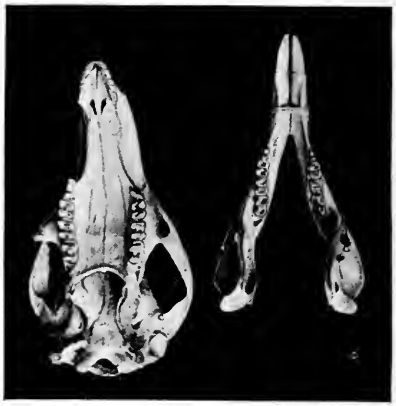
tusk in the Manatee, but no incisor teeth in the adult, and horny plates are supplied instead. Stellar's Rytina was a sea-cow that has become extinct within historic times. The last of the species inhabited Behring's Island. The dentition consisted mainly of horny plates which were used in cutting soft sea-weed. Some extinct forms of this family are found which suggest relationship with the tapirs, and it is probable that the ancestors of the Sirenia were connected with the land herbivora.

The *Marsupialia* is an extensive order which is low in organization, although the dentition is much varied and rather advanced. It includes all the pouched mammals which carry their young (born in a very immature condition) in the marsupial pouch upon the front of the abdomen for the completion of the gestation period. It comprises the Kangaroos, Opossum, Bandicoots, etc., all of which are native to Australia and the adjacent islands, except the American Opossum. The Marsupials represent a very primitive type of mammalian life, and stop at a stage which other mammals have long since passed. Teeth are present in most of the Marsupials, but they are usually monophyodont, as only one set is developed as a rule. Incisors are well developed, but the canines are feeble in most species. The Kangaroos have the formula,—

$$\text{i.}\,\frac{3-3}{1-1}\,\text{c.}\,\frac{0-0}{0-0}\,\text{p.}\,\text{m.}\,\frac{1-1}{1-1}\,\text{m.}\,\frac{4-4}{4-4}=28.$$

The upper central incisors are large cutting teeth; the lower centrals are large and chisel-shaped, and project forward horizontally with an interval between them. The two halves of the lower jaw are separate and movable, for shearing grass with the horizontal lower incisors. The canines are absent, and the premolars cutting and well developed.

FIG. 13.



Teeth of Kangaroo.

The molars have tubercular ridged crowns. The Bandicoots have canines and more incisors than the Kangaroos, with the molar series more cuspidate. The American Opossum has the formula,—

$$\text{i. } \frac{5-5}{5-5} \text{ c. } \frac{1-1}{1-1} \text{ p. m. } \frac{3-3}{3-3} \text{ m. } \frac{4-4}{4-4} = 50.$$

The incisors are small except the centrals, which are long and separated. The canines are long and

sharp. The premolars are sub-compressed. The upper molars are triangular in outline, and are an interesting survival of the primitive tritubercular type of the Eocene formations. The molar series have rather sharp cusps for the crushing of insect coverings. The Dasyure of Australia is more carnivorous than the Opossum, the canines being more developed and the molar series of more blade-

FIG. 14.

Teeth of Opossum.

like form. The Wombat is a heavy, clumsy Marsupial of Australia, with true rodent incisors. The insectivorous Marsupials have a dentition similar to the Insectivora. Other Marsupials are found, both fossil and recent, which are closely related to other orders as to dentition.

The *Insectivora* are so named on account of their peculiar diet,—the bodies of insects,—for which there is provided a peculiar dentition. The teeth are adapted to the crushing of the chitinous cover-

ing of insects, and for this purpose are armed with many points and long, sharp cusps. The best known members of the order are the Hedgehogs, Moles, and Shrews. The teeth are variable, but always bristle with cusps. The molars have a *W* pattern of the arrangement of the occluding ridges which is present in most of the order. The common English Hedgehog has the formula,—

$$\text{i. } \frac{3-3}{2-2} \text{ c. } \frac{0-0}{0-0} \text{ p. m. } \frac{4-4}{3-3} \text{ m. } \frac{3-3}{3-3} = 36.$$

In the upper jaw there is a wide interval between the first pair of incisors, which are very large and caniniform in shape. The second pair of incisors above are quite small and resemble premolars in form, the inner cingule being raised to a level with the edge. The third incisor has two roots, and is like a cusped premolar also. The canines are absent. In the lower jaw the first pair of incisors are large, but are not separated widely. The second pair are smaller, and the third pair larger and caniniform in shape. The canine is absent, but the first premolar has an oblique crown with five sharp cusps, one at each corner and a fifth on the inner side. The molars are reduced from this size, the last below having but one cusp. The upper premolars are square with four cusps, and the molars gradually decrease to the back, but bristle with cusps. The teeth of the Hedgehog are fairly typical of the order. The Shrews have the formula,

$$\text{i. } \frac{2-2}{2-2} \text{ c. } \frac{1-1}{0-0} \text{ p. m. } \frac{3-3}{3-3} \text{ m. } \frac{3-3}{3-3} = 34.$$

The incisors are remarkable in the Shrews. The centrals above are very large, are placed vertically, and are a little recurved or hooked. A cusp is developed behind the edge which makes a notch across the face, into which the tips of the lower incisors fit. The lower central is very large, lies horizontally, and has the point bent upward, with small tubercles raised to fit into the notch of the upper central. These teeth make very effective forceps for extracting insects from crevices in rocks or the bark of trees. The lower central extends backward and outward by a flange which overlaps the alveolar border of the jaw; it is one-third of the whole length of the jaw. The crushing teeth are rather small, but have the characteristic sharp cusps. The Moles have the formula,—

$$\text{i. } \frac{3-3}{3-3} \text{ c. } \frac{1-1}{1-1} \text{ p. m. } \frac{4-4}{4-4} \text{ m. } \frac{3-3}{3-3} = 44.$$

The first incisors above are small, but the third is large like the canines, and has two roots. The first two premolars are very small, then comes a very large one,—all being armed with pointed cusps.

The order *Cheiroptera* contains only the flying mammals,—the Bats. The modification of structure for flying—the long fingers with the membrane stretched between, the hooks for suspending, etc.—distinguishes these remarkable mammals from all others. They are closely related to the Insectivora in their dentition, as most of them subsist

on insects. The formula of the common red bat is

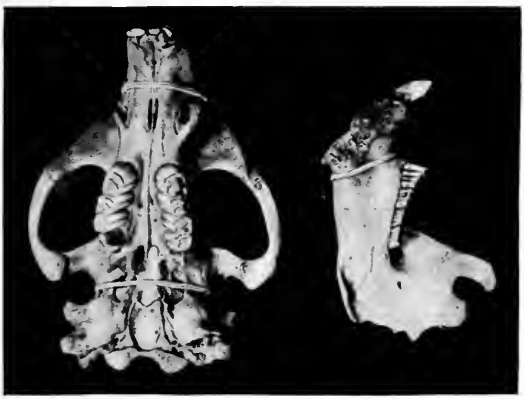
$$\text{i.}\frac{2-2}{2-2}\ \text{c.}\frac{1-1}{1-1}\ \text{p. m.}\frac{3-3}{3-3}\ \text{m.}\frac{3-3}{3-3}=36.$$

The canines are round and sharp, and the molars have sharp cusps with the insectivorous "W" pattern. This dentition is of great constancy. The frugivorous bats vary from the insectivorous in having the incisors larger, the canines reduced, and the molar cusps rounded. The Vampire bat is a remarkable form that sucks the blood of larger mammals. For this purpose the two upper centrals are wide and scoop-shaped, with sharp edges for puncturing the skin to draw blood. There are no other incisors above, but the canines are of about the same shape and size as the centrals. The other teeth are much reduced in size and shape, as the diet requires no dental manipulation.

The *Rodentia* are a very numerous order, and include such animals as the Beavers, Squirrels, Rabbits, Rats, and Mice. It is so named on account of their principal peculiarity,—*i.e.*, the two central incisors, one on each side of the median line, which are large, long, curved in a circle, and grow out of the deep parts of each jaw from persistent pulps, so that they are of continuous growth. The tissues are so arranged that the enamel is thicker on the front than on the back of the tooth, so that a sharp edge is preserved on the front by the wearing away of the rear portion, producing a chisel-shaped crown, hence the name given these teeth,—scalpri-

form. Continuous growth preserves the length of the tooth and the apposition of the edges. Wear and use are necessary to compensate for their growth, for if by accident an incisor becomes broken the opposite incisor continues to grow and curves around in a circle, piercing the soft parts of the head and producing death by starvation. Such

FIG. 15.



Teeth of Beaver.

accidents are not infrequent with rodents. The enamel of these teeth is usually of a light orange or reddish brown color. Sometimes there are two longitudinal grooves on the anterior surface. There are usually no deciduous predecessors to those teeth in rodents, except in the Hares, so that their monophyodontism is nearly constant. There

is an entire absence of lateral incisors, canines, and in some species of the premolars, in the order. The Hares have supplementary incisors behind the

FIG. 16.

FIG. 17.

Excessive Growth of Rodent Incisors.

upper centrals. The molar teeth are few in number, obliquely implanted, and present many varieties of the pattern of the grinding surface. Some-

times they have long roots, again short, or may be without roots, these differences being due to differences of diet. Those which subsist on a mixed diet or have a carnivorous tendency (as the true Rats), or eat only soft vegetable substances, as the oily kernels of nuts (as the squirrels), have the molar teeth less complicated in pattern and with small tubercles, and less firmly implanted. But those which subsist on hard substances, as the bark or branches or roots of trees, have molars with an arrangement of the tissues like the herbivorous Ungulata, in which hard wear produces a constantly rough surface. Such molars are of more or less continuous growth. In some rodents there are parallel plates of enamel placed transversely of the crown like the molars of the elephant, and like them there is a corresponding antero-posterior movement of the jaw. In some of the semi-carnivorous species, like the rats and mice, the molars are tuberculate, and much wear renders them cup-shaped like the much-worn molars of man. The American Beaver is one of the largest living members of the order. It has the formula,—

$$\text{i.}\ \frac{1-1}{1-1}\ \text{c.}\ \frac{0-0}{0-0}\ \text{p. m.}\ \frac{0-0}{0-0}\ \text{m.}\ \frac{4-4}{4-4} = 20.$$

It has exceedingly large, strong, scalpriform incisors, with which it cuts down small trees for the purpose of building the dams for which it is famous. The molars are strong, with the tissues arranged like those of the molars of the Ungulates for the purpose of reducing the resisting vegetable fiber on

which it feeds. The Hares and Rabbits have the formula,—

$$\text{i.}\ \frac{2-2}{1-1}\ \text{c.}\ \frac{0-0}{0-0}\ \text{p. m.}\ \frac{3-3}{2-2}\ \text{m.}\ \frac{3-3}{3-3} = 28.$$

In most species of this family there is a second incisor posterior to the central. The upper centrals have vertical grooves upon the anterior face which are also characteristic. The molars are remarkable for their great length, and grow continuously. They are tuberculate when erupted, but soon wear into a characteristic pattern. They have deciduous molars which are soon lost. The Squirrel family is very numerous. They usually have the formula,—

$$\text{i.}\ \frac{1-1}{1-1}\ \text{c.}\ \frac{0-0}{0-0}\ \text{p. m.}\ \frac{1-1}{1-1}\ \text{m.}\ \frac{3-3}{3-3} = 20.$$

The incisors are medium in size, and are strongly colored on the anterior face. The premolars are small, of triangular form, and implanted by three roots. The upper true molars are large, and are marked by two transverse crests. The lower molars have a central depression with a marginal ridge and with cusps at each corner. They have a premolar which is deciduous. The Porcupine's teeth are similar to the Squirrel's, except that the molars have three transverse ridges inclosing two valleys. In some of this family these crests and valleys are highly complicated. The common Rat has the formula,—

$$\text{i.}\ \frac{1-1}{1-1}\ \text{c.}\ \frac{0-0}{0-0}\ \text{p. m.}\ \frac{0\ 0}{0-0}\ \text{m.}\ \frac{3-3}{3-3} = 16.$$

Deciduous teeth are entirely wanting in this family,

so that it is monophyodont. The molars decrease in size from front to back, are simply tuberculate, and implanted by three roots. The tubercles are often worn away in aged individuals. The common mice have the same formula. In some the incisors are grooved and the molars may be without roots. The field mice have a trefoil pattern of the molars, or are triangular. There are many other living members of this order, but all have similar dentitions to these well-known examples. The fossil progenitors of this order were often of gigantic size. Some were highly specialized, and others with composite features resembling those of their living descendants.

The *Carnivora* is the great order of the flesh-eaters, the destroyers of animal life. It comprises the true Cats, the *Felidæ*, the Lion, Tiger, Leopard, the common cat, etc.; the *Canidæ*, dogs, wolves, foxes, etc.; the *Ursidæ*, bears, raccoons, etc. They subsist upon flesh, and to obtain this must destroy animal life, and are well equipped for the purpose by a highly specialized dentition, by their sharp, strong claws, and by their strength, speed, and agility. They are simply organized and highly specialized. There is little or no mastication of food and little digestion required, so the intestines are short, and the whole organization indicates a simple diet which is easily appropriated. In dental organization the Carnivora stand at one extreme end of high specialization, as the Herbivora do at

the other,—the flesh-eaters as opposite to the plant-eaters. We notice first the special hinge-like structure of the articulation of the lower jaw, which allows of but one motion,—*i.e.*, the vertical,—the mere opening and closing, without any lateral movement, so as to cause the long-bladed teeth to pass close to each other, for the purpose of cutting flesh fiber. The jaws are stout, to support the powerful muscles which are attached to them. The incisors are small and slightly tuberculate on the edge, the usual cutting function of these teeth being usurped by the long-bladed molars, which are now used only as scrapers for cleaning bones. The canines are long, conical or saber-shaped, curved, sharp, and piercing for seizing and tearing prey. The premolars and molars are compressed and raised into effective cutting blades for the division of flesh. They perform the cutting function instead of the incisors, and exhibit a high degree of specialization.

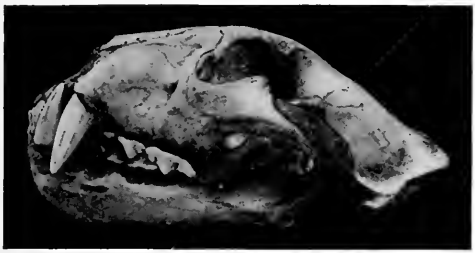
The *Felidæ* are the highest and most specialized as regards the teeth of the order. It includes the Lion, Tiger, Leopard, Lynx, and other cats. The usual dental formula is,—

$$\text{i. } \frac{3-3}{3-3} \text{ c. } \frac{1-1}{1-1} \text{ p. m. } \frac{3-3}{2-2} \text{ m. } \frac{0-0}{1-1} = 28.$$

The incisors are small, rounded and tuberculate. The canines are highly developed, being very long, strong, and deeply implanted. They are conical, or may be compressed and saber-shaped with

serrated edges, as in the saber-toothed, extinct Cave-tiger or the Clouded Tiger of India. The lower canine is well developed above, and closes in front of the upper into a space between it and the lateral, called the diastema. The first premolar is usually small, of a blunt, conical, or triconodont form. The second is larger, with a sub-compressed conical crown and a posterior, bilobed basal tuber-

FIG. 18.



Teeth of Indian Tiger.

cle. The third (and fourth, when present) are true sectorial teeth, and have the tubercles developed still further and divided into two blades, with or without notches, and the other tubercles are round and blunt for crushing. The principal blade is more or less deeply cleft in different species, with the prominences variously modified. The principal sectorial blade below is on the first true molar, which plays upon the inside and a little posterior of the body of the blade of the second or third upper

premolar. There is usually no true molar above, —usually one below,—or there may be a small tuberculate molar in some species which are less carnivorous. The lower premolars are more tuberculate, and play against the inside of the tubercles or blades of the upper. The main characters of the *Felidæ* consist in a reduction of the number of the teeth, their high specialization, the vertical movement of the jaw and the raising of the tubercles to resist this movement, the great muscles of closing, etc. The passage from the archetype bunodont tooth to the scissor-like carnassial sectorial form is plainly exhibited by a series leading from the lowest type up to the Felidæ. This form is due to vertical strain and growth, to resist the direction of jaw closing. The extinct Felidæ had a formidable dentition, extravagant in its specialization. The Cave-lion and Cave-bear and tiger were large and fierce, with a massive dentition which armed them well for preying on the great pachyderms of that period. The canines were immense, and in some curious forms, as the *Smilodon*, reached far below the jaw even when the mouth was opened wide. The great saber-toothed cat *(Machœrodus)* had great trenchant canines with denticulated edges, which caused the development of a wide flange beneath the lower jaw where the canine passed, like a sheath for its protection.

The *Canidæ* includes the Dogs, Wolves, Jackals, Foxes, etc. The formula usually is,—

$$\text{i.}\ \frac{3-3}{3-3}\ \text{c.}\ \frac{1-1}{1-1}\ \text{p. m.}\ \frac{4-4}{4-4}\ \text{m.}\ \frac{2-2}{2-2} = 40.$$

The teeth are reduced from the extreme carnivorous type of the cats, as the diet is mixed and the teeth respond to the changed conditions of food. The teeth are more tubercular, are reduced in specialization and increased in number to accommodate the increased demand for mastication.

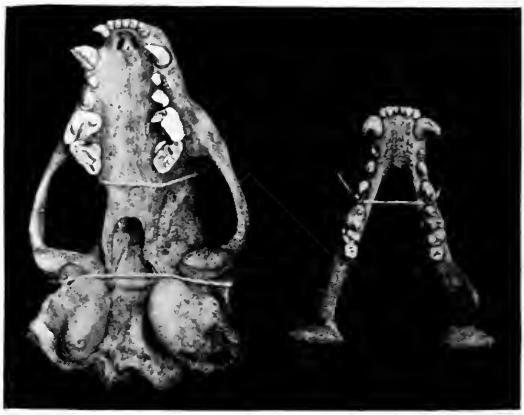
FIG. 19.

Teeth of Wolf.

The incisors are augmented in size, and often have a transverse groove on the edge into which the opposite tooth fits. The canines are reduced in length from those of the cats, and are more blunt, although the edges on both sides are still marked. The premolars are larger and stronger, the tubercles being rounded and reduced and more numerous than in the cats. The true molars are increased in number, are enlarged and more tubercular for

crushing purposes and the general change in diet. In the short-muzzled dogs, as the Pugs, some of the molar series are absent on account of the contraction of the jaws by breeding and the consequent lack of space for development. In the long-muzzled dogs, as the Hounds, on the contrary there is

FIG. 20.



Teeth of Badger.

increase of space, and additional molars are sometimes found.

The *Hyenas* are more carnivorous than the dogs, so that the tubercular teeth, the molars, are reduced, and the sectorial features increased. The premolars are stout and heavy for crushing bones.

The *Mustellidæ* includes the Ferrets, Weasels, Skunks, Badgers, etc. The formula is,—

$$\text{i. } \frac{3-3}{3-3} \text{ c. } \frac{1-1}{1-1} \text{ p. m. } \frac{4-4}{4-4} \text{ m. } \frac{1-1}{2-2} = 38, \text{—to } 36.$$

As these animals are predaceous or blood-sucking, their dentition is essentially carnivorous, though more sharp, long, and slender than that of the cats, but is modified for seizing and tearing the necks of animals for blood-sucking.

The *Ursidæ*—the Bears—have the formula,—

$$\text{i. } \frac{3-3}{3} \text{ c. } \frac{1-1}{1-1} \text{ p. m. } \frac{4-4}{4-4} \text{ m. } \frac{2-2}{3-3} = 42.$$

The teeth are still further modified from those of the dog, to adapt them to a still more mixed diet.

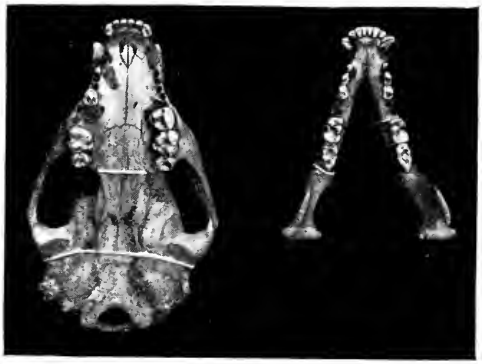
FIG. 21.

Teeth of Bear.

The incisors are notched on the edge; the canines are much reduced, but are strong and are ridged both on anterior and posterior surfaces. The premolars are dwarfed and are usually lost early,—seldom persisting through life. The molars are broad and tuberculate, and indicate a mixed diet.

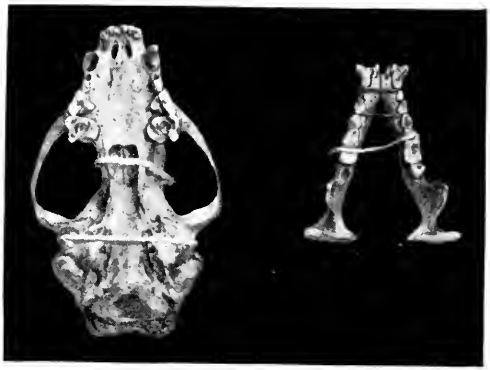
The *Procyonidæ* include the Raccoon, Coatis,

FIG. 22.



Teeth of Raccoon.

FIG. 23.



Teeth of Skunk.

etc. The teeth are tuberculate and omnivorous in character. The canines are sharp, with a posterior cutting edge. The premolars are reduced to flat crowns with sharp cusps, and the molars have sharp cusps, thus showing an insectivorous character.

The *Phocidæ* are the Seals, which have the formula,—

$$\text{i.}\ \frac{3-3}{3-3}\ \text{c.}\ \frac{1-1}{1-1}\ \text{p. m.}\ \frac{4-4}{4-4}\ \text{m.}\ \frac{1-1}{1-1} = 36.$$

The dentition is carnivorous, as they feed upon fish, and is simplified, and less highly specialized than in other Carnivora. The incisors are much reduced and often absent. The canine and even the molar series are simple and conical, being adapted to hold their struggling, slippery prey. The molar series are of typical triconodont form. In the Walrus the upper canines are elongated to form projecting tusks which reach far below the lower jaw. These are employed to assist in locomotion, to turn over rocks in seeking for food, and as formidable weapons of defense. In the Phocidæ the milk teeth are shed during fetal life in some species.

QUESTIONS TO CHAPTER VII.

(1) Which is the highest class of Vertebrates? Are the Mammals more highly organized than the Fishes, Reptiles, or Birds? In what elements do they live? Why are they called mammals? Why are they viviparous and the lower Vertebrates oviparous? How do they vary in size? What variety

of body coverings do they exhibit? How many limbs do they possess? Hence are called what? Describe the circulation, the respiration, the osseous system, the bones of the head and face.

(2) Do the teeth of mammals present great variety? Are they highly organized? Do they all possess teeth? What are the functions of the teeth in mammals as compared with lower Vertebrates? What relation do they bear to the digestive system? How do the teeth vary in numbers among mammals? How is the cone modified as compared with lower Vertebrates? What is the attachment of the teeth in mammals? Are the roots divided into more than one fang? How many and what tissues compose the teeth of mammals? How are these tissues found in mammals? Do they ever approach reptilian characters? Name such examples. Do the higher mammals differ from the lower, and how? Name some differences between the teeth of reptiles and mammals, and also some resemblances.

(3) What is the lowest order of mammals? What species does it contain? What sort of structures do they have instead of teeth? Describe the *Ornithorynchus*. What sort of dental substitutes does it have? What does the *Echidna* have instead of teeth?

What is the next order? What does it contain? Have the teeth any enamel? Are they monophyodont? What is the food of most of them? What of the peculiar tongue? What bones support the teeth? To what series do the teeth belong? Describe the form of the molars. How do the teeth wear in facets? What number do the armadillos have? What tissues are they mostly composed of? How do the teeth of armadillos articulate? How do they wear in consequence? What is the peculiar habitat of the sloths, and how are they constructed to accommodate their habits? Have they many teeth? To what series do they all belong? What is their form? Of what tissue are they composed? What fossil forms of the sloths are found, and where?

What is the next order? What mammals does the *Cetacea* include? What kind of teeth have the whales when present? What substitute for teeth does the Baleen Whale have? Of

what is it composed? How is it arranged? How does it originate? How many plates are sometimes found? How does the Whale procure food by means of the baleen? Are tooth-pulps sometimes found in the embryos of baleen whales? What sort of teeth do the Sperm-Whales have? What does the Narwhal have? Does the female have the tusk? How many and what kind of teeth does the Porpoise have? Also the Dolphin? Does the Dolphin have the most teeth of any mammal? Are the Cetaceans degraded? What low type do they approach? What animals are found in the order *Sirenia?* Are they herbivorous? How are the jaws and teeth of the Dugong constructed? Describe the incisors. Also the masticating plates and teeth. How many teeth has the Manatee, and of what form are they? What member of the Sea-cow family has recently become extinct?

Why are the *Marsupials* so called? What animals does the order comprise? Where are they mostly found? What one is common in North America? Are they a degraded form of mammalian life? Are they nearly all monophyodont? How many teeth has the American Opossum? Describe the incisors and canines. What remarkable form does the upper molar present? Is the triangular shape interesting, and why? What kind of incisors has the Wombat?

Why are the *Insectivora* so named? What mammals does the order include? How are the teeth specially adapted to the crushing of insects? What is the characteristic pattern of the molars? How many teeth has the English Hedgehog? Describe the central incisors; the canines; the premolars. Describe the upper centrals of the Shrews. Also the lower centrals. How are they adapted to form a forceps for extracting insects from crevices? How many teeth have the Moles? How are they formed?

Why are the *Cheiroptera* so named? How are the limbs modified for flying? Are they closely related to the Insectivora? What is the formula of the common red bat? What diet do the teeth indicate, and why? How is the dentition of the frugivorous bats modified, and why? Why are the grinding teeth more tubercular? What kind of incisors does the Vampire bat have, and why? What is its diet?

Why are the *Rodentia* so named? Is it a numerous order? Name some of them. What is the principal dental peculiarity? Describe the arrangement of the tissues in these incisors. How do they originate? Do they grow continuously? Is wear necessary to keep their length reduced? What occurs if a tooth is injured or broken, and why? What are the colors of these teeth on the anterior face? Are they ever grooved? Are there any lateral incisors or canines in this order? Are premolars ever present? What group have supplementary incisors behind the centrals? Are there many molars present? How are the tissues arranged to keep them rough as in the Herbivora? What effect does diet have on the form of the grinding surface of these molars? Are those of the mixed feeders more tuberculate? Are those of the vegetable feeders more rough for harder grinding? What is the difference in the implantation of the mixed and vegetable feeders? How are the plates of enamel arranged as to jaw movement? Give the formula of the Beaver. For what hard duty are its incisors constructed to perform? How does it build its dam? How are the plates of the molars arranged? What is the formula of the Hares? Have they the supplementary incisors behind the centrals? Are the centrals grooved on the labial face? How many teeth have the Squirrels? Are the incisors strongly colored? How are the molars marked? What is the formula of the common Rat? Is it a monophyodont? Are the teeth tuberculate for a simple diet? What are some of the peculiarities of the teeth of Mice?

What is the name of the next great order? Why *Carnivora?* What does it comprise? Upon what do they subsist? Are they highly specialized? Are they at one extreme of high dental specialization? What order is at the other end? On what do they subsist? How are the Carnivora highly specialized as regards the teeth and digestive apparatus? What of the articulation of the jaws? How is it constructed, and for what purpose? Why has it no lateral movement? Of what form are the incisors? Why are they reduced? What teeth perform the cutting function? Describe the canines. Why are they most developed in this order? What is the highest family of the Carnivora? What animals does it include?

What is the formula of the Felidæ? Describe the canines of the Felidæ; the first premolar; the second; the third. How are the cutting blades formed? Are there any true molars above? What is the sectorial tooth below? Against what tooth above does it close? What are the main features of the Felidæ? How are the teeth modified from the bunodont to the carnassial form? What were the extreme fossil types found? What are the *Canidæ?* What teeth are added to the formula of the Felidæ? How is the specialization reduced, and why? Do the dogs have a more mixed diet? Are the teeth more tuberculate in type in consequence? How are the incisors altered? The canines? The premolars? What variations are found in the short and long muzzled dogs? What is the type of dentition of the Hyena, and why? What does the *Mustellidæ* include? What is the formula? What is the type of dentition, and why? What is the formula of the Bears? How are the teeth modified, and why? What are the peculiarities of the *Procyonidæ?* What is the formula of the Seals? How are the teeth modified, and why? What primitive type do the molars present? Why triconodont? How are the canines of the Walrus enlarged? Describe these tusks.

CHAPTER VIII.

THE TEETH OF MAMMALS (Continued).

The *Ungulata* is that great division of hoofed quadrupeds which are herbivorous in food habits and form the other extreme as opposed to the carnivorous animals. There are two great divisions of the Ungulata,—first, the *Artiodactyla*, the even-toed Ungulates (the Ox, Deer, Sheep, Pig, etc.), and second, the *Perissodactyla*, the odd-toed Ungulates (the Horse, Rhinoceros, Tapir, etc.). The dental system of this great branch presents extreme modification for adaptation to an exclusively vegetable diet, and is highly elaborated and complex. It is the extreme of specialization in the herbivorous direction. The molar teeth are of the folded or lophodont type, the tissues being folded on the sides of the crown and the valleys dipping down into the crown so as to form high, sharp crests which, when worn away, present curious patterns of the arrangement of the dental tissues. As opposed to the vertical direction of the movement of the jaw in the Carnivora, in this order the jaw movement is horizontal, the articulation being wide and loose, so that the grinding teeth are spread out and developed laterally to resist the transverse movement so necessary to the grinding of refractory vegetable fiber. The lopho-

dont type of molars has, of course, been gradually developed from the simple bunodont or tubercular type, by increasing the number of tubercles and ridges and their erection into sharp crests and ridges. The lateral excursion of the jaw is more extensive in some forms,—as the ox, deer, etc.,—and in these the molars present a lateral extension of the grinding surface. There is always a corresponding modification of the condyle and the glenoid cavity to accommodate the movement, and the corresponding development of the teeth due to lateral motion is most remarkably shown. There are deep transverse valleys and high crests, and the plication is greatest in the direction transverse to the jaw movement. The crests have been flattened and bent oblique, or folded about in various directions, which have produced a variety of patterns of grinding surface where the teeth are much worn. This gives a peculiar arrangement of the dental tissues, and looks as if the enamel, dentin, and cementum had been laid together and rolled and crushed and the ends of the roll presented for mastication. The different densities of the three tissues produce different degrees of wear, so that the grinding surface is always rough to be more effective for the reduction of vegetable fiber. The enamel being hardest stands highest, and traces the pattern of the surface; the dentin being next in density stands lower, and the cementum being softest is most worn out. The patterns of the ar-

rangement of the folds of enamel thus presented are very various throughout the order, but each family have the same type of pattern, and this is so constant as to have a distinct diagnostic value for the distinguishing of species, especially in fossil remains. Different groups of the Ungulata are characterized by a distinct pattern of the arrangement of the tissues of the molars, that is exact and constant.

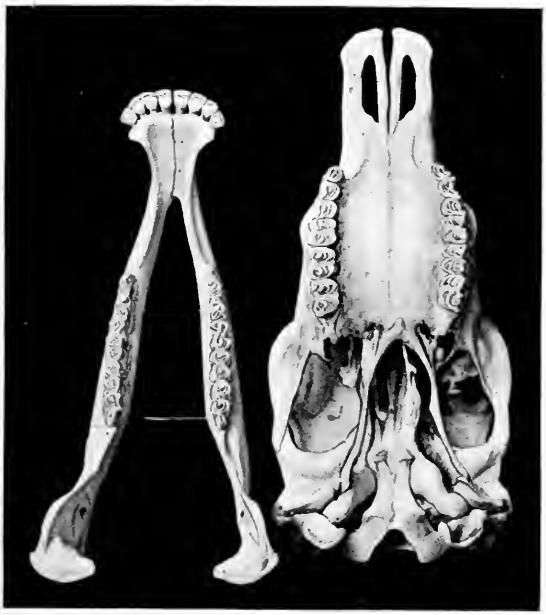
In the *Artiodactyla*,—the even-toed Ungulates,—the first and most important group is that of the *Ruminants*,—those herbivora which regurgitate the bolus of food from the stomach to subject it to a second chewing or rumination. This division includes the Ox, Sheep, Deer, Antelope, Giraffe, and indeed the greater part of the Artiodactyla, which have no incisors in the upper jaw. The formula is usually,—

$$\text{i.}\ \frac{0-0}{3-3}\ \text{c.}\ \frac{0-0}{0-0}\ \text{p. m.}\ \frac{3-3}{3-3}\ \text{m.}\ \frac{3-3}{3-3} = 30.$$

There are no incisors nor canines in the upper jaw, but instead a hard pad of cartilage covered with dense gum-tissue, against which the lower incisors and incisor-like canines close in cutting off grass. Rudimentary incisors are met with in the Red-deer, and the Musk-deer, Water-deer, and Muntjac have formidable upper canines projecting downward below the lower jaw for weapons and digging roots. The canines bear a more or less distinct inverse relationship to the presence or absence of

horns,—*i.e.*, when the upper canines are present the horns are absent, or *vice versa*. The molar teeth of this group present great variety as to the pattern of

FIG. 24.



Teeth of Cow (*Bos taurus*).

the grinding surface, but within families are much alike. Thus the molars of the ox family, the deer family, etc., have each a distinct and characteristic pattern which is unmistakable. The *Camelidæ* includes the camels and dromedaries. The two

first pairs of incisors above are absent, but the third pair are canine-like in shape, and the canines are large and formidable. The first premolar above is like a canine, and the presence or absence of the other two varies much. The type of the molar is selenodont. The non-ruminant, even-

FIG. 25.

Teeth of Hog (*Sus scrofa*).

toed Ungulates include the Pig, Hippopotamus, etc. The formula of the Pig is,—

$$\text{i. } \frac{3-3}{3-3} \text{ c. } \frac{1-1}{1-1} \text{ p. m. } \frac{4-4}{4-4} \text{ m. } \frac{3-3}{3-3} = 44.$$

The Wart Hog has but thirty-four and Dicotyles thirty-eight teeth. The incisors are well developed, and increase in size from center to sides. The canines are sometimes enormously developed, as in the Wild Boar. This development is arrested in the domestic hog by castration, showing that the excessive growth is due to sexual influence. The

canines are small in the female. In the Wild Boar they curve outward and upward into hooks to make formidable weapons for ripping up an adversary. They sometimes pierce the upper lip, are triangular in section, and are deeply ridged on the exterior surface, the enamel being rough and irregular. The lower canines are much smaller. The molar series increase in size from front to back, and present sharp, high crests which usually remain unworn in the domestic hog. When worn the crests present a characteristic triangular form. The Hippopotamus is much like the pig as regards its dentition, but has four incisors less. There is a monstrous development of the ill-shaped incisors and canines, which are large, blunt, and variously directed so that their edges, ends, or sides may be worn on different surfaces. They are coarse and tusk-like, and nearly cylindrical in form. The upper incisors are implanted vertically and the lowers horizontally. The canines are enormous, trihedral in shape, and are of persistent growth. The molars have sub-compressed conical crowns which have two lobes, each divided into two half crowns, with a crucial depression separating the four cusps. Each cusp is formed in a definite trilobed shape which wears into a characteristic trefoil pattern, like the pig. Sometimes the molars are quadrilobate when much worn.

The *Perissodactyla* are much less numerous as regards their living representatives, although great

numbers have lived on the earth in past geological times. It includes the Horse, Rhinoceros, Tapir, and their allies. The Horse family has the formula,—

$$\text{i.}\ \frac{3-3}{3-3}\ \text{c.}\ \frac{1-1}{1-1}\ \text{p. m.}\ \frac{4-4}{4-4}\ \text{m.}\ \frac{3-3}{3-3} = 44.$$

The incisors are broad, thick, and slightly curved, with a valley dipping down into the crown which

FIG. 26.

Teeth of Horse.

when worn produces the well-known mark by which the age of a horse is estimated. The canines are long and cubical in the male, but smaller in the female. A considerable space exists between the canine and the premolars. The first premolar is rudimentary, and often becomes a source of irritation. It is popularly called the "wolf-tooth," and is soon shed. The other premolars are often as large and complex in pattern as the true molars.

The upper molar crowns are cubical and large. The grinding face presents a peculiar pattern which is distinctive of all varieties of the genus *Equus*, both living and extinct. The molars are rather of an archaic pattern, and not so complicated as in the Ruminants. The characteristic crescents of

FIG. 27.

Teeth of Rhinoceros.

the lower molar ridges are much like those of the Rhinoceros. The phylogeny of the horse has been well made out, and the pattern of the teeth has played an important part in this most interesting scientific triumph.

The Rhinoceros has the formula,—

$$\text{i.}\ \frac{3-3}{3-3}\ \text{c.}\ \frac{0-0}{0-0}\ \text{p. m.}\ \frac{4-4}{4-4}\ \text{m.}\ \frac{3-3}{3-3} = 40.$$

when the full quota is present. The incisors of the

Rhinoceros bear an inverse relationship to the development of horns,—*i.e.*, when the horns are present the incisors are reduced or absent, and when the horns are absent these teeth are augmented. The two-horned species have no incisors in the adult individual. The incisors vary from four to eight,—some having the centrals missing and others the laterals. The canines are absent in all species. The grinding teeth increase in size from before backward, and differ from those of the horse by being implanted by distinct roots. They present a characteristic pattern which is found in both extinct and recent species. The little Biblical Coney (Hyrax) is unique in that it is closely allied to the Rhinoceros in the pattern of its molars. The central incisors are very large, and similar to the rodents. The laterals are smaller, and are soon lost. The lower incisors have denticulated edges which bite upon a callous pad behind the upper incisors. It has the formula,—

$$\text{i.}\ \frac{2-2}{2-2}\ \text{c.}\ \frac{0-0}{0-0}\ \text{p. m.}\ \frac{4-4}{4-4}\ \text{m.}\ \frac{3-3}{3-3} = 36.$$

The Tapir has the formula,—

$$\text{i.}\ \frac{3-3}{3-3}\ \text{c.}\ \frac{1-1}{1-1}\ \text{p. m.}\ \frac{4-4}{3-3}\ \text{m.}\ \frac{3-3}{3-3} = 42.$$

The incisors are round, and with a transverse groove between the edge and the basal ridge into which the lower incisors fit. The outer incisors are long and caniniform. The canines are rather small and pointed. The lower incisors are smaller than the upper. The molar series are partly tuber-

culate and partly triturating on the surface; the lowers are of double transverse ridge type. There were many extinct forms of the Rhinoceros and Tapir which had similar dentitions, and by which the remains are readily recognized.

The *Proboscidæ* are the large mammals which have a long proboscis,—the living Elephant, the extinct Elephants, Mammoths, Mastodons, etc. Only two species are now living,—the African and Indian Elephants. The Mastodons, Dinotherium, Mammoth, and several Elephants are now extinct on the earth, and can only be studied in fossil remains. The order is almost entirely extinct, and the living species of Elephants can only be preserved by domestication and care, as they have been remorselessly destroyed for the ivory furnished by the long tusks. The order is distinguished by the long incisor tusks, which are implanted in deep sockets in the premaxillary bones, and grow continuously from persistent pulps. The bulk of the tusk consists of finely-tubed dentin which constitutes the ivory of commerce. The tubules bend and curve, which makes the fine ivory lines and causes the refraction of light which is one of the beauties of fine ivory. The present trade in ivory is enormous, and comes from Africa, where the elephants have been destroyed by thousands, so that the wild species will soon become extinct. Formerly the fossil beds and Arctic shores and islands of Siberia yielded great quantities of the

tusks of the extinct Mammoth, and they are yet washed up by the waves. Of the two living species of the Elephant the formula is,—

$$\text{i. } \frac{1-1}{0-0} \text{ m. } \frac{6-6}{6-6} = 26.$$

Fig. 28.

Teeth of Elephant.

The two upper central incisors are greatly prolonged into the form of round, curved tusks, which sweep outward and upward to the length of several

feet. The African Elephant has larger tusks than the Indian species, and they sometimes reach the length of eight feet and weigh one hundred and fifty pounds. The tusks are incisors and not canines, which is shown by the fact that they are inserted in and supported by the premaxillary bones, which are enlarged and prolonged to support them. These tusks grow from persistent pulps, and are subject to disease and injuries. Gunshot and spear wounds sometimes reach the pulp in the immature portion of the tooth, and give rise to abscesses which affect the development of the dentin. Sometimes resorption of the root is caused by the larva of a dipterous insect in India, and the tusk is so weakened that it breaks off. There are no lateral incisors or canines in the Elephant, and probably no premolars, although from the peculiar mode of succession of the molars the premolars and true molars cannot be distinguished. Six molar teeth are developed on each side of each jaw which succeed each other from behind forward, moving in a groove. One molar, or parts of two only, are in use at one time, and when one is worn out it has been pushed up to the anterior end of the groove, where it is partially absorbed and shed. Its successor then advances slowly to take its place, and is shed in turn. The series are in continual process of formation and destruction, of shedding and replacement, until the last molar comes into place when the animal is old and remains through the

rest of life. The first of the molars is in place at three months, and has but four plates of enamel. The second follows at two years, and has eight or nine plates. The third follows about the fifth year, and has eleven to thirteen plates, and is four by two inches in size. The fourth follows in the ninth or tenth year, has fifteen to sixteen plates, and is eight by three inches in size. The fifth molar appears at the twentieth year, has seventeen to twenty plates, and is ten by three inches in size. The sixth molar appears ten to twenty years later, has twenty to twenty-seven plates, and is twelve to fifteen inches in length. This lasts until the close of the animal's life, which may be a century. These molars are very complex and remarkable in structure. Each consists of a series of transverse, oval plates like flattened circles of enamel, the central space being filled with dentin, the bulk of the crown between and around the plates being made of cementum,—the unequal density of the tissue producing a rough surface for grinding, as in all Herbivora. The occluding surfaces are originally tuberculate with crown crests, like the molars of the Mastodon, but these soon wear down and expose the plates, which are arranged transversely to resist the antero-posterior movement of the jaw. These plates present different patterns in the Indian and African species; in the former they are of parallelogram or diamond shape with zig-zag foldings of the enamel rim, and in the African species the plates are

lozenge-shaped, or flattened circles, and the rim of enamel is smooth and even. Each enamel plate is developed from a separate tooth-pulp.

The majority of the members of this order of gigantic mammals are now extinct, though some of them have survived to recent geological times. The Mammoth of Siberia and glacial Europe was a great hairy elephant, with enormous tusks sweeping upward and backward in a circle. His remains have been found in the flesh frozen in the ice of Northern Siberia, and his image has been discovered carved on his own ivory and upon reindeer horns by his contemporary, primeval man, in the glacial caves of Europe.

The bones of Mastodons are found all over the United States in recent formations, and are sometimes associated with the bones and implements of prehistoric man. The Mastodon had the formula,

$$\text{i.}\ \frac{1-1}{1-1}\ \text{p.}\ \text{m.}\ \frac{3-3}{3-3}\ \text{m.}\ \frac{3-3}{3-3} = 28.$$

It had four incisor tusks,—two above and two below in the center of the jaws. The upper tusks were large, thick and strong, and sometimes attained the length of twenty feet, describing a sweeping curve outward. The two lower tusks were small, straight, and projected horizontally forward. The molars of the Mastodon differ from those of the Elephant, but are plainly the type of the forerunners of the latter. The latter have similar cusps to the former, when erupted, but

soon wear down to the characteristic plates, the separate denticles taking the form of dentinal plates. The grinding face of the molar of the Mastodon had transverse ridges which supported two teat-like tubercles. The first molar had two such ridges and four tubercles. The second had three bifid, transverse eminences and a tuberculate ridge on the rear of the crown. The third molar had four ridges and occasionally five, and a posterior talon. The intervening valleys were at first filled with cementum, but this wore out with use. The extinct *Dinotherium* had the upper tusks absent and the lower prolonged into downward-curving tusks. It was aquatic in its habits, and employed the anomalous tusks for digging aquatic plants. Its molars were similar to those of the Tapir.

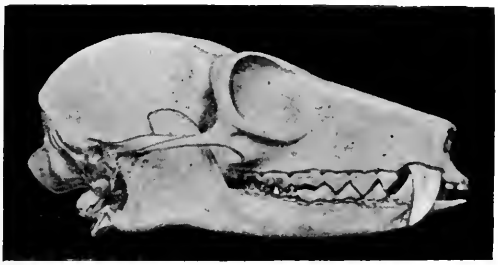
The *Primates* (or *Quadrumana*) comprise those mammals having four hands,—the Lemurs, Monkeys, and Apes. They are distinguished from all other mammals by having opposable thumbs on both the hands and feet which enable them to grasp objects. The Primates include also those members of the animal kingdom, the Apes, which stand next to man in structure and whose dentition is exactly like that of man. Although thus approaching man, the teeth are still like the lower mammals, arranged in a parallelogram instead of the rounded arch of man. The skull is small, and the teeth and jaws are still prominent and prognathous. The

Lemurs are the lowest of the Quadrumana, and connect that order with the lower mammals in many features of structure. They have the formula,

$$\text{i. } \frac{2-2}{2-2} \text{ c. } \frac{1-1}{1-1} \text{ p. m. } \frac{3-3}{3-3} \text{ m. } \frac{3-3}{3-3} = 36.$$

The upper incisors are small, and are separated from each other by wide spaces. The lower incisors project straight forward and interdigitate with the upper, passing into the interdental spaces. This

FIG. 29.



Ruffed Lemur (*Lemur varia*).

enables them to cut up the tender shoots of bamboo, twigs, grass, etc., on which they feed, with facility. The upper canine is large and pointed, with sharp edges. The lower canine is like the incisors in form, and ranges forward with them. The premolars are sub-compressed, and have long, sharp cusps. The first upper premolar is large and caniniform. The others are lobed and have a small internal cusp. The fourth is like the true molars, which are made quadrangular by the in-

ternal cingulum rising up into a cusp at the posterior angle of the crown. In some forms, as the Spectre-lemur, the teeth are of insectivorous type for the peculiar diet. There is often a basal ridge on the incisor, which is well defined even on the anterior face. The inner cingule on the incisors is like those of the Moles. The molar series are inclined to be trihedral. The *Galeopithecus* is remarkable for having the lower incisors, which are broad and flat, cleft to the base by deep vertical fissures, so that they resemble the teeth of a comb. There are seven such fissures, making eight columns in the central and nine in the lateral incisors. The upper centrals are broad, flat, and notched, as are also the third incisors and canines. The molar series are simple and tuberculate. The *Aye-Aye* (Cheiromys) has a dentition of the rodent type, with similar continuously-growing, scalpriform incisors. The lateral incisors, canines, and most of the premolars are absent, the molars having an elliptical grinding surface. Other forms of Lemurs present different varieties of dentition. They are the survivors of that primitive type of Quadrumana which were the progenitors of the *Anthropomorpha* of to-day,—including man,—which are found in the Eocene formations of the West. One genus—*Anaptomorphus*—had the generalized characteristics of the progenitors of the Primates. It had the tritubercular upper molar, and a monkey of the later Eocene had the quadritubercular form

such as is found in the later Primates and man to-day.

The true monkeys are divided into two great classes,—first the *Platyrrhinæ* (wide-nosed), or New World Monkeys, and second the *Catyrrhinæ* (narrow-nosed), or Old World Monkeys. The Platyr-

FIG. 30.

Teeth of New-World Monkey.

rhine, or American Monkeys, have prehensile tails, wide nostrils, and the dental formula, usually, as the Cebidæ,—

$$\text{i.}\ \frac{2-2}{2-2}\ \text{c.}\ \frac{1-1}{1-1}\ \text{p. m.}\ \frac{3-3}{3-3}\ \text{m.}\ \frac{3-3}{3-3} = 36.$$

Halpiadæ has but thirty-two teeth. The presence of the third premolar in this branch, along with

other peculiarities, indicate that they are nearer the Lemurs than the old world Primates, and are therefore lower in structure. They have stopped at a lower stage of development, and the Old World branch has progressed. The Catyrrhine, the Old World Monkeys, and Apes have the formula,—

$$\text{i. } \frac{2-2}{2-2} \text{ c. } \frac{1-1}{1-1} \text{ p. m. } \frac{2-2}{2-2} \text{ m. } \frac{3-3}{3-3} = 32,$$

FIG. 31.

Teeth of Old-World Baboon (*Cynocephalus porcarius*).

which is exactly that of man. There is one less premolar on each side of each jaw than in the New World Monkeys. However, of the latter, the little Marmoset has only thirty-two teeth, owing to the absence of the third molar on each side, although they still have the third premolars. The Platyr-

rhines have the third premolar in the deciduous set also. Some species have nearly horizontal incisors, —another lingering lemurine characteristic,—but the teeth as a rule begin to approach the erect position. The incisors are thick and strong, and of nearly the same width. The canines are strong and prominent, and appear before the last molars. The diastemas in front are well marked, into which the lower canines close, as in the Carnivora. The molars usually have two transverse ridges with four cusps. In some forms the oblique ridge, a remnant of the tritubercular stage, is retained. The disto-lingual cusp is added to complete the quadritubercular form. Some of the American monkeys —as the Marmosets—have sharp cusps, showing an insectivorous diet. The *Howlers* have large, strong canines projecting from both jaws. The uppers have the deep anterior grooves. The premolars are trihedral, with three pointed cusps on the buccal line, triconodont. The true molars are quadritubercular except the last, which is tricuspid The dentition of the American monkey is, on the whole, rather low and lemuroid. The *Capuchins* have lower incisors with broad, thick, wedge-shaped trenchant crowns, which is the characteristic form of these teeth throughout the Quadrumana. The canines are strong and pointed. The upper premolars have two cusps on a transverse line, the outer one being longest and largest. The first premolar below has the trenchant ridge

continued forward from the outer cusp, like the Baboons of the Old World. The true molars decrease in size from first to last, and are all quadricuspid except the third below, which is tricuspid. The dentition in general of the Platyrrhines is thus rather uniform.

The *Catyrrhinæ*, or Old World Monkeys, have the same dentition as man as to number, and the human forms of the teeth are gradually approached in advancing from the lower to the highest species. The upper central incisors gradually become wider and the laterals narrower. The lower incisors become narrower, and are less thick and heavy. The canines remain strong and powerful, but are reduced in some species. The Mandrills have these dental weapons most formidable for their size and shape, and the uppers descend behind the lower canines against the edge of the lower first premolar, which is raised to meet them. This is a marked peculiarity of the Baboons. A large diastema separates the upper canine from the incisors, into which the sharp lower canine closes. The premolars gradually assume the bicuspid form, but the cusps are large, long, and sharp. The true molars have four prominent sharp-pointed cusps with an anterior and posterior basal ridge. They progressively increase in size from the first to the third in all the Baboons. The crowns of the lower molars are narrower and longer than the upper, and the last has a fifth lobe or tubercle. The first lower

premolar is bicuspid or unicuspid, but the second is quadricuspid. In the long-tailed monkeys, the upper molars have four tubercles, and the lowers five. In some Catyrrhine monkeys the curved form of the arch begins to appear. In some the teeth have long, sharp cusps, indicating an insectivorous diet. In most of the higher species they are tuberculate, as in man, indicating a mixed diet. The deciduous set are the same as those of man and succeed each other similarly, but with some variation as to the time of the eruption of the teeth.

QUESTIONS TO CHAPTER VIII.

What is the next great order? Into what two great sections is it divided? What does the *Artiodactyla* include? The *Perissodactyla?* Is this group at the other extreme from the Carnivora, and why? Are the teeth very complex and highly specialized, and why? What is the type of the molar teeth? How are the tissues arranged? How is the form elaborated from the simple bunodont type? Are the tubercles raised into crests? How is the pattern of the grinding surface formed? What is the jaw movement in the Herbivora, as opposed to that of the Carnivora? What is the difference in the articulation of the jaws? What effect does jaw movement have on tooth forms? How does the horizontal movement of the jaw affect the form of the molars? Do the crests and ridges bend and fold in various directions? Why does vegetable fiber require this elaborate mastication? How are the teeth made to be effective for grinding? How do the different densities of the dental tissues cause the rough surface by irregular wear? How do the tissues wear? Does each group have a distinct pattern of the arrangement of the

enamel? Is this sufficiently constant as to be diagnostic? What is the highest group of the Artiodactyla? Why are they called Ruminants? What does it include? What is the formula? Do they have incisors or canines in the upper jaw? Are the grinding teeth of the highest type of specialization? Does each genera have a distinct pattern of the grinding surface? What species of deer have upper canines? Does the presence or absence of canines bear any relation to the presence or absence of horns? Describe the characteristics of the teeth of the *Camelidæ*. What are the non-ruminant Artiodactyla? How many teeth has the Pig? Do the canines develop larger in the Boar? Are they sexual in their presence and growth? Give some of the characteristics of the canines. Of the molars. Describe the teeth of the Hippopotamus. How are the incisors and canines shaped, and how do they wear? What is the general form of the molars? Into what kind of a pattern do they wear? What species are included in the Perissodactyla? What is the formula of the Horse? What is the form of the incisors? How is the "mark" made? Which premolar is rudimentary? What is the general type of the molars? Is the pattern primitive? What are the peculiarities of the teeth of the Rhinoceros? How does the presence or absence of incisors bear a relation to the presence or absence of horns? Describe the molar teeth. What are the peculiarities of the teeth of the Biblical Coney? Do its molars resemble those of the Rhinoceros? What are the peculiarities of the teeth of the Tapir?

Why are the *Proboscidæ* so called? What mammals does it include? How many species are now living? What is the distinguishing feature? What remarkable incisor tusks do they have? How are the central incisors developed? Of what tissue is the tusk mainly composed? What is this tissue called in commerce? Where does the supply mostly come from? Where does fossil ivory come from? What animals supplied it in Siberia? What is the formula of the Elephant? How large do the tusks of the African Elephant sometimes become? Why are the tusks incisors and not canines? How do they grow? Are they subject to injuries? How many molar teeth are there in the Elephant? How do they succeed

each other? Is the process of loss and reproduction continuous? At what ages do these molars appear? What is their structure? Of what do they consist? What is the main tissue of the tooth which holds the plates together? How are the plates arranged? Why transversely in relation to jaw movement? What different patterns do the plates exhibit in the Indian and African Elephants? Does each plate grow from a persistent pulp? What are the extinct members of the order? Where was the Mammoth found? Was he associated with primitive man? What great species was found in North America? What was the formula of the Mastodon? Were there tusk incisors below as well as above? Of what size and form were the upper central incisor tusks? Also the lower tusks? Of what form were the molars? Describe the grinding surface. How many ridges had the principal molars? What form of tusks had the extinct Dinotherium?

What is the highest order of mammals next to man? Why *Quadrumana?* Do the higher members approach man? Is the dentition of the Apes like that of man? How does the dental arch differ from that of man? Also the skull and jaws? What is the lowest family of the Quadrumana? What is the dental formula? Describe the incisors. The canines. The premolars. The molars. Are they often of insectivorous type? What remarkable lower incisors does the Galeopithecus have? How are the upper incisors shaped? What lemurs have rodent incisors? What fossil forms of the lemurs have been found? What are their specialized features? Into what two great sections are the true monkeys divided? What is the distinguishing feature of the Platyrrhine monkeys? The Catyrrhine? What is the dental formula of the American monkey? Of the Old World species? Is the latter like that of man? Which is the extra tooth in the American monkey which is absent in the Catyrrhines? Are the former more lemuroid? What species has only thirty-two teeth, and why? Do the incisors incline and begin gradually to approach the erect position? Describe the canines of the Platyrrhines; the incisors. What is the diastema? Is it found in nearly all the Quadrumana? Describe the molars. Does the oblique ridge begin to appear? Describe the teeth of the *Howlers.* Of the

Capuchins. Have the Catyrrhines, the Old World monkeys, the same dental formula as man? How do they approach the human type? How does the comparative size of the central and lateral incisors approach that of man? How are the canines in the Catyrrhines? How is the first premolar below modified to form a cutting edge against the descending upper canine? What is the general form of the molars? How does the dental arch become modified? Is the deciduous set the same as that of man?

CHAPTER IX.

THE TEETH OF THE HIGHER APES AND MAN.

(1) The higher Apes (the *Anthropomorpha*) include the Gibbons, the Orang, Chimpanzee, and Gorilla. They differ markedly from the lower Primates in many respects, *i.e.*, in having no tails and no callosities; in habitually assuming a semi-erect attitude; the broader thorax; the elongation of the forearm so as to support the body on the fingers or knuckles, etc. They are largely arboreal in their habits.

The jaws are of a more or less parallelogram shape, the rounded arch of man being but little approached in the Apes. The skull is small and depressed, and the jaws large and prominent, so that the prognathism is very marked.

The teeth are similar in number and form to those of man, and approach his in all the essential features of their structure, although there are some differences as to arrangement, texture, squareness of form, etc. The central incisors are wider than the laterals, as in man; the lower Primates, especially the Lemurs and Platyrrhines, having the incisors of nearly the same width, and the difference becomes apparent as the advance is made from the lowest to the highest forms.

The great canines stand out at the corners, and

are large and trenchant like those of the Baboons, and there is still a large diastema in front of the upper canine into which the lower one closes.

The premolars are of the bicuspid type, but are coarse and large, with strong, high, sharp cusps. They are implanted by three roots above and two below, just like the true molars and like the lower Primates. The molar teeth are large, square, and coarse, and increase in size from front to back, the reverse being the rule in man. They are of the distinctly human pattern,—quadritubercular above, quinquitubercular below.

The teeth of the Apes resemble those of man in various degrees, but there are conspicuous differences which can best be tabulated as follows:

(a) Relatively to the size of the cranium, the jaws and the teeth are very large and prominent in the Apes. Hence they are very prognathous, and the facial angle is low. In man, on the contrary, the jaws are much reduced, the cranium is enlarged and brought forward, and the facial angle is nearly vertical.

(b) The dental arch is a long parallelogram in the Apes, like the lower mammals. In man the arch is shortened and rounded to form a graceful curve.

(c) The teeth of the Apes are of irregular height, the canines standing above the level of the rest. In man no one tooth surpasses another in height, but all are on the same level.

(d) In the Apes there is a diastema in front of the canine above into which the lower canine closes. In man there are no spaces between the teeth, but they are in regular continuity in the series in both jaws.

(e) The incisors in the Apes incline forward more or less, and by their projection increase the prognathism. In man the incisors in both jaws are vertical, except in some of the low races with distinct prognathism.

(f) In the Apes the canines are very large and long, with sharp edges behind like the Carnivora, and are larger in the male than in the female. In man they are reduced to a level with the other teeth, the animal features are obliterated, and there are no sexual differences in these teeth.

(g) In the Apes the molar series increase in size from front to back, and follow a straight line. In man they decrease in size from first to last, and follow a curved line.

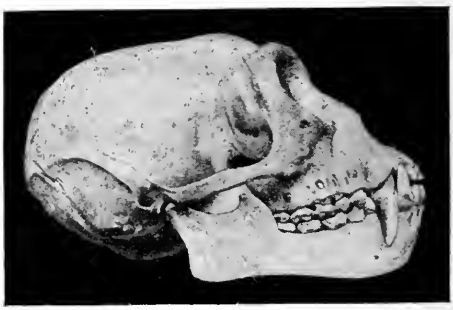
(h) The third molar is the largest of the series in the Apes, and has ample room in the jaw. In man it is the smallest of the molar series, and is crowded for space on account of the shortening of the jaws.

(i) The teeth in general are larger, thicker, and coarser in the Apes, are more square and angular, and the cusps and edges more prominent and sharp. In man the teeth are smaller and finer in texture, the crown is narrower and rounder, the

angles are reduced, and the cusps and edges are short and blunt.

The resemblances are also marked in the exact formula and number, but all the resemblances are not found in the Apes. Thus in the little Celebes monkey the teeth are in close contiguity as in man. The oblique ridge of the upper molars is found in the higher Apes, but also in some of the American

FIG. 32.



Teeth of Gibbon.

monkeys. In man the canines are cut before the third molars, but in the Apes not until afterward, etc.

(2) *Descriptive.* The *Gibbons* are the lowest of the tailless Apes, and are found in the Malay archipelago. The incisors are of the human type, but the difference between the centrals and laterals is not so marked as in the higher Apes; they being more nearly of one width, like the lower Quadrumana. The canines appear simultaneously with

the third molars, and are of a smaller, conical type than the other Apes. The premolars are large and heavy, but of the low, Simian type.

The true molars are sub-equal in width, but more reduced than those of the other Apes, and more human.

The *Orang-Outang* also inhabits the Malay archipelago. It is quite human in its dentition, but the Chimpanzee and Gorilla are nearer man in many other respects.

The upper centrals are of great size, and are twice as wide as the laterals. They have basal ridges on the internal face.

The laterals are pointed, the distal edge being obliquely truncated and the mesial edge rounded so that but a point appears. A diastema as wide as the laterals separates them from the canines. The lower incisors are of nearly equal width, and long and stout.

The canines in the males are long, strong, and slightly curved without the anterior groove of the Baboons. They are much larger than the other teeth, and are imperfectly trihedral, with a trenchant edge behind and a ridge running from the lingual cingulum to the point. These teeth are smaller in the female. They do not appear until after the third molars are in place. The lower canines are sharp-pointed, with a marked lingual ridge.

The upper premolars are smaller than in the

Baboons, the cusps of the first being more pronounced than those of the second. The outer cusp is the larger. The lower first premolar has a subacute point with three ridges descending internally. The second is bicuspid in form.

FIG. 33.

Teeth of Orang-Outang.

The first and second true molars above are larger than the third. There are four tubercles, but these are rather reduced. The enamel of the grinding surface is finely wrinkled. The lower molars have five tubercles, three externally and two internally. The third is five-lobed, with a wrinkled face.

The *Chimpanzee* is a medium-sized man-ape

found in West Africa. The dentition is strictly quadrumanous, but approaches the human type in many particulars.

The central incisors are reduced from those of the Orang, so that they are smaller and the laterals larger than in the latter ape, which is a lower form. Each incisor has a prominent basal ridge. The laterals are larger, but still have the distal corners rounded off. The lower incisors are large, and project forward.

The diastema between the incisors and canines is narrower than in the Orang.

The canine is much smaller than in the Orang, is conical, and with a sharp posterior edge. It is not cut until after the third molar is in place. In the female it follows the second molar, and is much smaller. As in the Orang, it is so long as to extend below the lower alveolar border when the mouth is closed. The lower canines are smaller, conical, and trihedral, and with a sharp inner edge.

Both upper premolars are bicuspid, the exterior cusp being most pronounced. The lower first premolar is larger than the second, and is twice the size of the human tooth. It is shaped like the Baboon's, with a sharp anterior edge with two sharp trihedral cusps. The second lower premolar is subquadrate, with three tubercles.

The true molars above are quadricuspid, and are relatively larger than the bicuspids; in the Orang they are relatively smaller. There are five cusps

on the lower molars, the two inner ones being sharpest. The tubercles are rounded and more prominent than in man.

The *Gorilla* is the largest of the Primates and Apes, and approaches nearest to man in general organization. The Gorilla, with the Chimpanzee,

FIG. 34.

Teeth of Gorilla.

is found in the Gaboon region of West Africa. Although close to man in many details of organization, the dentition of the Gorilla is not so human as that of some of the lower Primates. That of the Chimpanzee is more close. The diastema is still wide, and the canines are large and baboon-like. The jaws are large and square, the arch is a mere

parallelogram, and the brain-case is much smaller. The great ridges erected to support the muscles of mastication are very conspicuous. The incisors are of similar shape to those of man, and the relative sizes of the central and lateral are nearly the same as that of man. The crowns are coarse, square, heavy, and roughly ridged. The canines are of great size and strength, quite like those of the Baboons. The crown is trihedral in section, with a groove on the labial face and a cutting edge behind. It stands out in such prominence as to give a ferocious look to the face, and adds to the squareness of the jaws. It is not as large in the female as in the male. They erupt after the third molar; in man before this tooth is in place. The upper premolars are of bicuspid form, as in man, but the cusps are more high and pointed, and are united by a strong cross ridge. The uppers are implanted by three roots. The lower first premolar is strong, pointed, and caniniform. The second is tricuspid. Both are implanted by two roots, like the true molars. The upper molars are more strong and square, the cusps sharper and longer, than in man, but have the oblique ridge. These teeth are not so human as those of the Chimpanzee and Orang. The lower molars are similar and have the same pattern as in man, but the second has the fifth cusp, which is wanting in man. The third molars are larger than the others, as the molar series increase in size from first to last; in man the reverse is true. They have

ample room in the jaws, and are useful grinders. The grinding teeth are very strong, as the massive muscles of this great Ape are used for biting and crushing with tremendous force.

(3) *The Teeth of Man.* The teeth of Man are closely related in form and structure to those of the apes below him, and remotely to various members of the Quadrumana. Indeed, like other organs, they bear in their structure the history of a long line of descent, and many of the indications of their history can be read with some certainty. Some of his teeth are quite primitive in type, as the quadritubercular molar, which is found far back in the Eocene; and occasionally this lapses into the still more primitive form of the tritubercular molar. The teeth of Man in general are degraded in form and structure, and much reduced in specialization as compared with, for instance, the highly specialized teeth of the Carnivora and Herbivora. The structural integrity of the teeth is much more deficient in civilized man than among savage races, of course, although dental diseases are not unknown among the latter. There is not so much of a gap between the higher species of the Apes and the low races of Man as might be supposed, scarcely more than between the lower and higher races of Man. As the teeth of Man are strong and well made, they approach the Simian form and integrity; as they are defective and ill-formed they depart from it. The best dentures are

those which have animal perfection of organization. The reversions to lower forms often presented by the teeth of Man are of peculiar interest, and exhibit their descent and animal relationship in a remarkable degree. The teeth of Man being rudimentary as compared with the lower Primates, these reversions are not unexpected. Some of the instances of reversion may be noted as follows: Man has but thirty-two teeth, while the typical mammalian formula is forty-four. He has thus lost twelve teeth, some of which sometimes reappear as so-called "supernumerary teeth," but are in reality due to atavism, and are reversions. Thus a third incisor, or third bicuspid, or fourth molar are sometimes seen; the upper incisors may be scoop-shaped (like the Shrews or some Lemurs), or may have a cingulum on the base, like the Quadrumana; or may be deeply ridged or notched (as it always is at birth), recalling the cleft incisors of the Galeopithecus, etc. The upper lateral is very erratic, and, like the third molar, seems to be on the road to extinction. It is sometimes absent, or may be reduced to a mere peg shape; or it may be bicuspid by the raising of the lingual cingule, like the incisors of the Insectivora. The canine is sometimes strongly marked by the ridges or a cingule, which it shows in lower forms; the upper bicuspids sometimes have three roots, as in the Quadrumana; the upper molar is sometimes tricuspid, which is a lemurine form, and reaches far back into Eocene

times. The second lower molar occasionally has the fifth cusp, which is the anthropoid type; but this cusp is wanting in the higher races, though often present in the lower. The lower third molar is sometimes wrinkled on the face, like the molars of the Orang, etc.

The prehistoric and other low races of mankind stand nearer to the Apes in many essential points of structure than the highly developed and advanced races. This is illustrated by many items of anatomy, and markedly so in regard to some features of the dental organization, in which they differ from the higher races in many points in which they approach the Apes below them: the arch is not so rounded, but it is more square in front; the third molars have ample space, and are as large as the other molars; the jaws are prominent and prognathous; the teeth are well arranged, and irregularity is uncommon; the roots of the third molar are separate, like the other molars,—in the higher races they are fused together; the second lower molar has the fifth tubercle, etc.

As the higher races vary from savage strength and perfection of the teeth, it is in the direction of incompleteness and imperfection. The best dentures among European races are those which have the animal perfection of form and organization, so that the differences that distinguish the teeth of the lowest savage from those of the European are much the same as mark the change from the

anthropoid to the human type, though the latter are far greater. The large size of the jaws of the savage is due to the harder work to which the teeth are put, owing to the hard and often gritty nature of the food used by savages. For the same reason the teeth of low races are much worn with age, which does not always obtain among civilized races. In a general way the savage has what we would call a good set of teeth, if it were found in the mouth of a European; but the massive jaws are among the most marked of structural traits of low races. The use of the teeth as tools, until superseded by tools made by hands, also caused the greater development of the parts.

The fossil remains of Man found in Europe show the ape-like features of the teeth and jaws very strongly. The prominent superciliary ridges and glabella were accompanied by massive zygomatic arches, jaws, and mandible, and a retreating chin like the Apes. The posterior molars were as large or larger than the other molars, which increase from front to back; the lower molars were often elongated like the Apes; the lower molars all have the fifth tubercle, which is missing in the second molar in later Man; the bicuspids were large and thick, and of large size in proportion to the molars; the cusps were high and sharp, but, like the tubercles of the molars, became much worn in adult age with rough usage; the canines were heavy, long, and sharp, being more of the baboon type; the

incisors were long and thick; the centrals and laterals were more nearly of the same width, like the teeth of the anthropoid Apes.

The teeth are very degenerate in tissual organization among the higher, *i.e.*, European races, but this is due not to the mere fact of civilization, but to the enervating effects of the luxuries and vices of civilization, to which they succumb. The higher races do not live near enough to the energizing influences of nature, but by surrounding their lives with enervating luxuries and degrading vices induce weaknesses which transmit degenerate organization. From this cause the teeth of the higher races have suffered much. Savages as a rule have good, strong teeth, but their physical organization is also sometimes degenerated by lack of nourishment or by disease. Their teeth also then partake of the general deficiency, and become deteriorated in structural integrity also. This fact shows that dental degeneracy and disease is due to deficiency of general structure, strength, and integrity, for the teeth are among the first of tissues to be affected by disturbance of the nutritive supply.

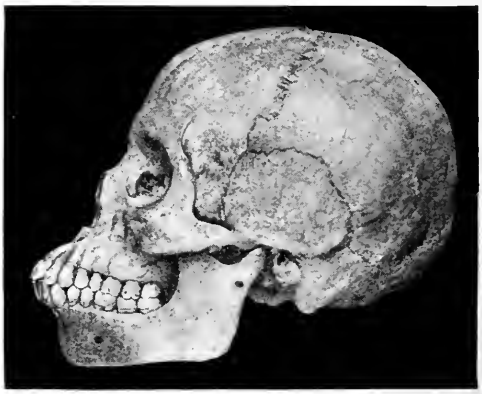
The teeth of civilized man are much reduced in size as well as structure, and also the strength of their supporting environments, by disuse. The gradual lessening of the function of mastication, and the reduction of the force and variety of jaw movements, has led to a marked weaken-

ing and degradation of the dental mechanism in Man. Growth force has been reduced by disuse, and the whole apparatus has become more or less rudimentary, in accordance with the law of economy of growth in unused parts. The jaws are much contracted through disuse,—so much so that there is often lack of space for the teeth to erupt in proper position. This produces irregularity of the arrangement of the teeth, and, in the case of the third molars, leads to serious disturbances, owing to shortening of the jaws and lack of room for them to come into place. The teeth are also disappearing through economy of growth due to disuse, as evidenced by the degraded third molar, which is often stunted in form and frequently absent entirely. The upper lateral incisor also is occasionally stunted and sometimes absent, and seems to be following the path of those teeth of man which have passed into oblivion, only to be recalled by their occasional reappearance as supernumeraries.

In regard to the *racial differences* of the teeth, it is well known that the lower races approach the Simian type and mark the transition to the human form. They belong to what are called the *Macrodont*, or large-toothed races. The most prominent of the latter are the *Australians*, who are the lowest of living races and most ape-like. Their teeth are large, white, and well formed. The molars do not decrease in size from front to back, but

tend to increase or are of nearly the same size. The second lower molar has the fifth cusp, just like the Apes. The canines are large and conical. Supernumerary teeth—especially fourth molars—are not uncommon. The jaws are massive, with a monkey-like squareness in front, and are very prognathous. In the New Caledonians and some

FIG. 35.



Fan Tribe, West Africa.

other Australoid people the central incisors are so large and insectivorous-like as to show their form through the lips.

The *Negroid* races have teeth that are large, thick, dark-colored, coarse, and ape-like, and project forward. The molars are large (macrodont); the roots of the third molar are distinct, and the molars are of the same size, or increase from front

to back. The second molar below usually has the fifth cusp. The third molars are usually of good

FIG. 36.

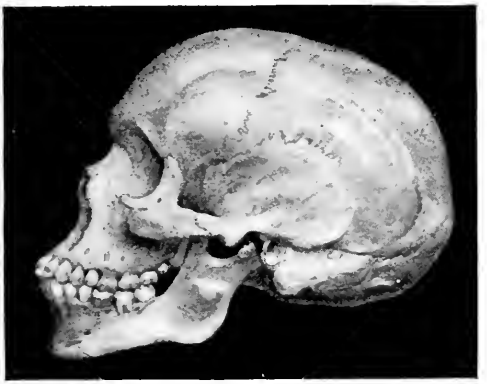


FIG. 37.

African Negro.

size, as large or larger than the other molars, and fourth molars are not uncommon in the black races.

The canines are large and conical, the teeth are well set and regular, and the anterior teeth stand apart. The arch is parallelogram in form, with square corners, and the prognathism is well marked. The facial bones partake of the general dolichocephaly of the cranium. The prominence and massiveness of the mandible is such that the wear of the lower incisors is ofttimes toward the inside, and of the upper incisors toward the labial surface. The alveolar process is thickened about the roots of the teeth to form prominent ridges just beyond the necks. The gums are dark or mottled, the pigmentation of the skin extending even to the mucous surfaces. Some of the Polynesian negroes have small arches, with small, finely-formed teeth.

The *Mongoloid* races have the jaws rounded in relation to the brachycephalic skull, although still prognathous. The teeth are macrodont, with rather heavy prominent tubercles and cusps. The bicuspids are large as compared with the molars,—a Simian feature. In the Chinese the teeth are large and white, the anterior teeth being obliquely placed. The teeth of the Japanese are similar to the Chinese, but smaller, as the race is small-boned. The Eskimos have rather small teeth, with round arch, the third molars being often reduced in size and sometimes wanting. The upper molars are often tritubercular. The Malays have Mongolian teeth, but are much disfigured by betel-nut chewing and mutilating customs.

The *Indians* of America are generally macrodonts, the teeth being large, strong, and well set in a round arch. There is considerable variety exhibited among the divers races of North and South America, large, medium, and small teeth being all found. Deformities are not infrequent, and fourth molars and third incisors sometimes occur. The teeth are much worn with age, like all savage people living on a coarse diet. The Mound-builders had fine teeth, in a round arch, which when not worn were large, yellow, and squarely set and coarsely made. The ancient Aztecs had small arches and small, fine teeth, but the Mexican peon of to-day has defective teeth, owing to deficient nourishment and disease. Deformities and dental diseases are not uncommon among them. The Indians of the United States of later times had large, fine teeth, but, with the degeneracy and disease incident to the vices acquired from the white man, they become degenerate and defective.

The *European* races of to-day are descended from two distinct types,—the light and dark,—which are named *Xanthochroid* and *Melanochroid* types, respectively. The Xanthochroid sub-races are the light-complexioned people of Scandinavia, Germany, the British Isles, the Libyans, the ancient Etruscans, and others. The teeth of the light races are rather large, square, light in color, and with square jaws and prominent canines. The skull being usually dolichocephalic, the jaws are

FIG. 38.

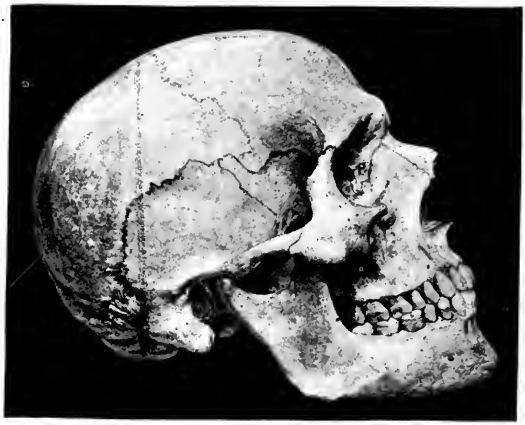
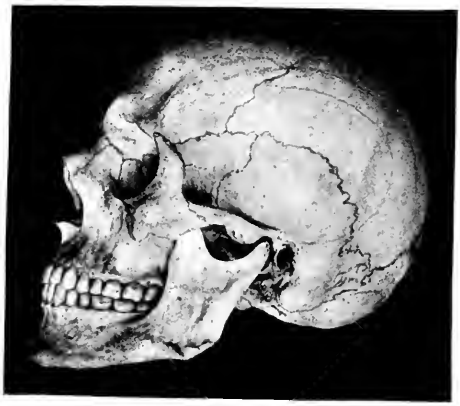


FIG. 39.



European (Caucasian).

narrowed also, but are not often prognathous. With highly civilized and luxurious, or poorly nourished lower peoples, these teeth are rather deteriorated in structure and prone to caries. This is noted even in the skulls of ancient Britons, Etruscans, and others, who were more or less civilized and luxurious. The prehistoric ancestors of

FIG. 40.

European (Caucasian).

these people had teeth of better structure than their descendants. The Melanochroid, or dark races, include the dark types of Europe, the Mediterranean people, the Slavs, the Semitic branches, the ancient Egyptians, the Persians, Hindoos, and other dark Aryan races. They are usually brachycephalic, with a round dental arch, and are microdonts,—*i.e.*, small-toothed,—as are also the Xanthochroids, but the latter are more properly meso-

donts,—*i.e.*, of intermediate size. The teeth are small, of fine shape, closely set in a round and graceful arch, of medium color, and rather better organized than those of the light races. The deleterious influence of the luxuries and vices of civilization of course affects them, but among the wilder and stronger branches of the dark race the teeth are strong and fine. One peculiarity of this type is the tritubercular upper molar which is prone to appear in the Latin races.

But the light and dark races of Europe are so interminably intermixed that ethnic features of all kinds are much confused. In this confusion the racial characteristics of the teeth are practically lost and beyond identification. The principal effect of intermixture has been deterioration of the teeth, by accumulation of the weaknesses of both types and derangement of the symmetry of the dental arch by the crossing of small jaws with large teeth. This is one cause of crowded arches and irregularities of arrangement of the teeth. The descendants of Europeans in America are especially subject to the ill effects of this intermixture of races, to which have been added the deleterious influences of strange climates, irregular habits, and the feverish pursuit of the elusive pleasures of so-called civilization. The consequent physical degeneracy has been reflected in the teeth of Americans to an extraordinary extent.

QUESTIONS TO CHAPTER IX.

(1) Which are the higher Apes? How do they differ from the lower Primates? How do the skull and jaws differ from those of man? How do the teeth compare with those of man? What are the peculiarities of the incisors? The canines? The premolars? The molars? What are some of the differences between the teeth and jaws of the Apes and of man? (a) In regard to the jaws and cranium? (b) In regard to the dental arch? (c) The height of the teeth? (d) The diastema? (e) The inclination of the incisors? (f) The canines? (g) The size of the molar series? (h) The third molar? (i) The quality of the teeth? What resemblances to man are found in the Quadrumana in different branches?

(2) Which is the lowest of the Apes? What are some of the peculiarities of its teeth? The next highest? What are some of the peculiarities of the teeth of the Orang? What of the comparative size of the central and lateral incisors? What is the next Ape? Does the dentition of the Chimpanzee approach that of man? What in regard to the centrals? The laterals? The canines? The premolars? The molars? What is the highest of the Apes? Does the Gorilla approach man in general structure? Is its dentition as human as that of the Chimpanzee? What of the arch and jaws? Describe the incisors; the canines; the premolars; the molars.

(3) Are the teeth of man close to those of the apes in form and characteristics? What teeth are low and primitive in type? Are they degraded in form and structure? Are they highly specialized as compared with the teeth of some mammals? Are they defective as they depart from animal perfection? Do the teeth of man present some curious reversions of forms? Describe some of them. Do low races approach nearer the anthropoid type than the higher races? Give some items of resemblance. Are the teeth of the higher races more imperfect? Do they lose animal perfection? How has use and disuse affected the growth of the teeth and jaws? What dental peculiarities are found in fossil man? What Simian features do the teeth and jaws present? Do the teeth of savages become much worn with use, and why? What is the

cause of tissual degeneration of the teeth of the higher European races? Do savages generally have good teeth? Are they affected by degenerate physical organization, and from what causes? Are the teeth and jaws of civilized man reduced, and why? How does disuse affect the parts? How is the eruption of the third molar affected by the shortening of the jaws? What teeth are now disappearing through disuse?

What is a *macrodont* race? Are the low races macrodont, and why? Describe some of the dental peculiarities of the Australians. Are the Negroid races Simian in their dental features? Describe some of these in various negro races. What is the form of the skull and jaws? Are the Mongolian races macrodont? What are some of the dental peculiarities of different Mongolian types? Do the Indians of America present much variety in their teeth? Describe some of them. From what two types are the European races of to-day descended? What are the light races called? The dark races? What people belong to the Xanthochroid type? What is the general form of the skull and jaws? What is the general type of the teeth? Are they of rather poor structure in the civilized nations of this type? What peoples do the Melanochroid or dark type include? Are Europeans microdonts, and why? Are the dark races brachycephalic? What is the form of the arch in the dark and light types? What is the type of the teeth in the dark races? How does the deleterious influence of civilization have a bad effect upon the quality of the teeth also? Are the light and dark races much intermixed in European peoples? Has racial intermixture affected the teeth badly? How has it affected the form of the arch and arrangement of the teeth? How have the teeth of the American descendants of Europeans suffered from race mixture and other deleterious influences?

DENTAL
LIBRARY